CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

JANUARY, 1954. **Vol. XLIX, No. 1**

FORTY-NINTH YEAR OF PUBLICATION

Price 1s. 6d. [This number 2s. 6d.] Annual subscription 18s., post free. $3·90 in Canada and U.S.A.

LEADING CONTENTS

PAGE

Roads 1

Prismatic Roof Slabs with Small Angular Change. *By A. J. Ashdown* 3

Building at London Airport 14

Water Tower at Glasgow 18

A Garage in London: Curved Beams Spanning 194 ft. . . 23

A Factory with Shell Roofs 29

Prestressed Bridge for a Railway and Coal Conveyors . . 35

Lining the Haslingden and Walmersley Tunnels. *By O. Dawson, B.Sc., and A. S. Bertlin* 43

REINFORCED CONCRETE STRUCTURES
Recently Completed and in Course of Construction

No. 554. ISSUED MONTHLY *Registered for Canadian Magazine Post*

A

Testing concrete on site saves money and avoids delay

ERICHSEN Power and Hand Operated

Compression Testing Machines

THE MODEL ILLUSTRATED weighs 397 lb., and can be supplied up to a maximum capacity of 250 tons for 6-inch cubes. A machine for 4-inch cubes is also available. Not only will an Erichsen machine prove a first-class investment on reinforced and prestressed concrete contracts, but on post-tensioned prestressed concrete work it is indispensable. It completely eliminates the expense, inconvenience and delay caused by waiting for test results from a distant laboratory.

4-in. CUBES

may be used when the aggregate does not exceed ¾ in.—*The British Standard Code of Practice No.* 114 (1948).

PEARSON PHILLIPS

Pearson Phillips Limited, 194-196 Finchley Rd, London N.W.3.
Telephone: HAMpstead 3866.

Calculation, Design and Testing of REINFORCED CONCRETE

Second Edition

By

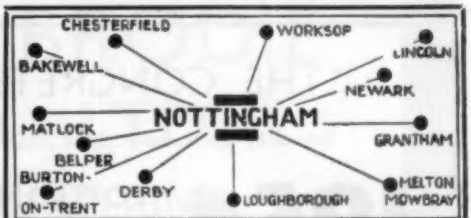
K. L. RAO

M.Sc., Ph.D., M.I.C.E., M.I.Struct.E., M.I.E.(Ind.)

Now revised and brought up to date, this book mainly represents the course of work in reinforced concrete that is covered by the civil engineering students of Loughborough College, and covers the syllabuses of the examinations for the B.Sc. Engineering Degree, the Associate Membership of the Institution of Civil Engineers and the Institution of Structural Engineers. An important study for all concerned with building and architecture.

Over 400 pages. 35s. net.

PITMAN Parker St · Kingsway · W.C.2



Trent Gravels

10,000 tons per week

Washed & Crushed 1½ in. to ¼ in.

We are the leading suppliers of high-class concrete aggregates in the area shown above. Prompt deliveries guaranteed and keen competitive prices quoted. Send for samples and prices.

TRENT GRAVELS LTD

ATTENBOROUGH NOTTS

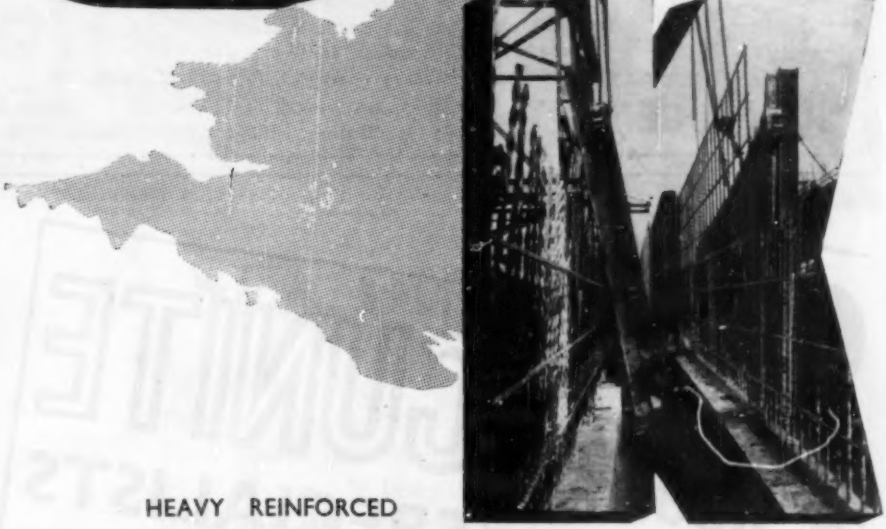
Telephone: Beeston 54255.

"CONCRETE SERIES"

BOOKS ON CONCRETE

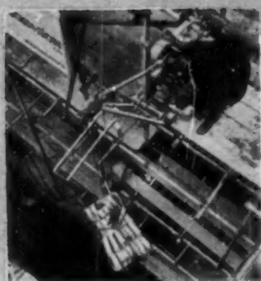
For a complete catalogue giving prices in sterling and dollars, send a postcard to:

CONCRETE PUBLICATIONS, Ltd.
14 Dartmouth St., London, S.W.1



ACE MIDGET HOIST

Saves time and money on every kind of contract



12 TRUMP POINTS!

- Low purchase price with negligible running and maintenance costs
- Easy to install and easy to move to other locations
- 5 cwt. capacity to handle barrow loads, beams, lintels, etc.
- Faster speeds for triple bucket duty and lighter loads
- Adjustable radius up to 5 ft.
- ACE top trip prevents overwinding
- Winch quickly detachable from jib for separate use if required
- Snap action hook for changeover of rope reeve, dismantling or assembly
- Load taken on 4 scaffold tubes increases safety
- Built to last
- Petrol or electric drive
- PROMPT DELIVERY

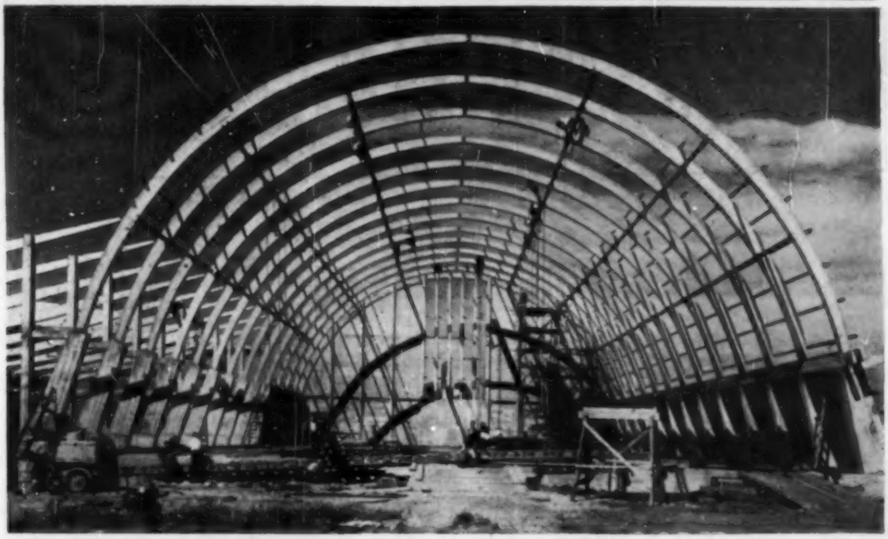
Write for illustrated leaflet

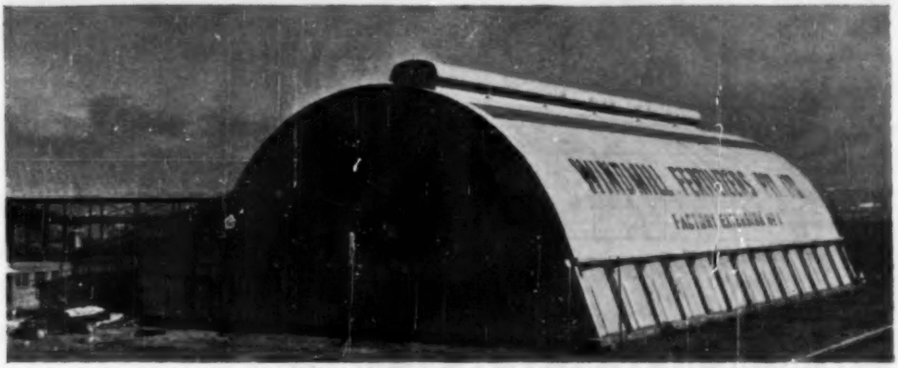
Demonstrations can be arranged

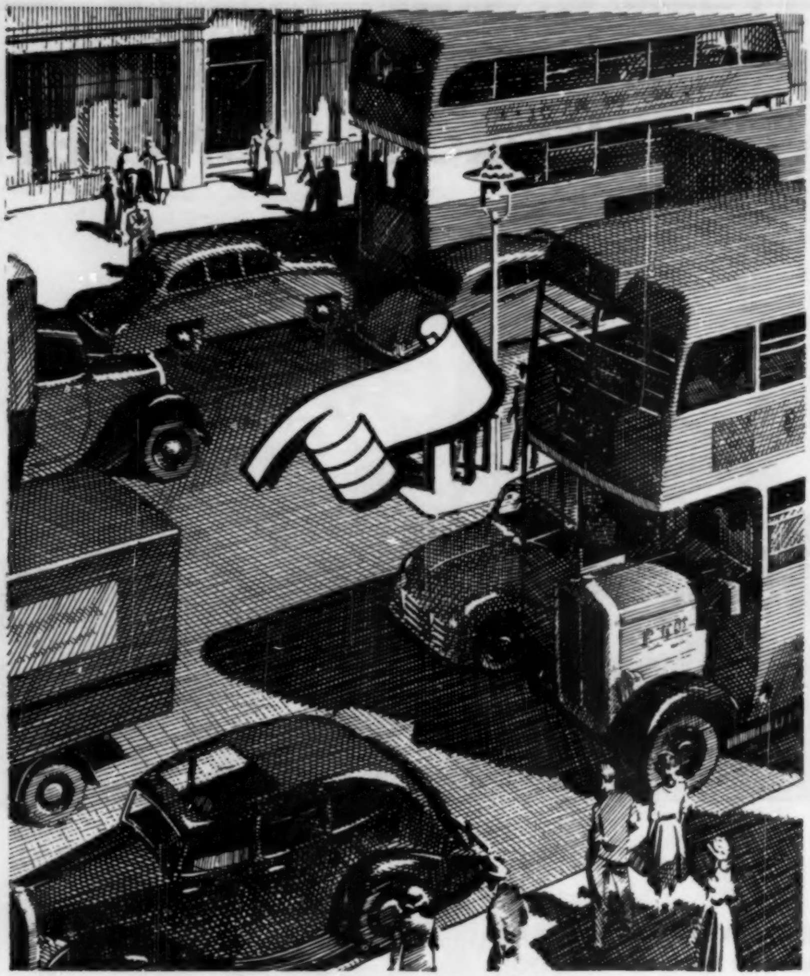
ACE
PLATFORM HOISTS · WINCHES

ACE MACHINERY LTD., PORDEN ROAD, BRIXTON, LONDON, S.W.2
Telephone: BRIxton 3293 (9 lines) And at Brentford

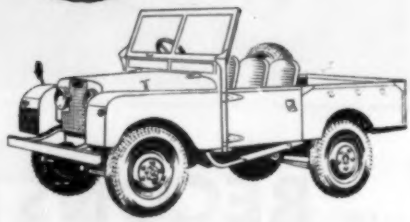
Buy ACE and you buy RELIABILITY







Big new features FOR THE IMPROVED LAND-ROVER



By increasing the wheelbase to 86″ (a foot longer overall) the designers have given the improved Land-Rover a 25% bigger bulk carrying capacity. This extends the already impressive range of tasks for which this sturdy vehicle is suitable. At the same time the greater axle movement resulting from the longer propeller shaft gives much improved suspension. Facia instruments are scaled-up, there is a full-width parcel shelf and improved pedal arrangement for greater comfort and safety.

There are three roomy, comfortable front seats—and the lover of big car comfort on workaday activities will welcome the deep cellular rubber sprung seating, the new high-efficiency sealing on the all-weather equipment and the improved ventilation. The 86″ wheelbase model is, in fact, an all-round improvement of Britain's own all-purpose vehicle.

★ **LONGER WHEELBASE-86″**

★ **BULK-CAPACITY 25% UP**

★ **IMPROVED SUSPENSION**

★ **CAR-TYPE INSTRUMENTS AND CONTROLS**

★ **CAR-LIKE COMFORT**

LAND-ROVER

new 86″ wheelbase

the **4-WHEEL DRIVE** *"go anywhere" vehicle*

MADE BY THE ROVER COMPANY LTD · SOLIHULL · BIRMINGHAM also DEVONSHIRE HOUSE · LONDON

CVS-89

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING
INCLUDING PRESTRESSED CONCRETE

Volume XLIX, No. 1. LONDON, JANUARY, 1954.

EDITORIAL NOTES

Roads.

THE rolling English road of G. K. Chesterton does not appear to be in any great danger of being straightened or levelled to a noticeable extent by the recent proposals of the Government to spend an extra £50,000,000 on road and bridge works in addition to the sum allowed for minor improvements and repairs during the next three years. This expenditure is much less than many had hoped, and the work is to consist largely of major improvements rather than new construction, thus leaving the main road system generally unchanged. It is, however, a beginning of the long overdue reconstruction of our roads, on which few major works have been carried out for fifteen years or so. During this period there have been many improvements in mechanical methods of concrete road construction, notably in the U.S.A., and some of these methods have been used in this country for the construction of runways at airfields. Some British contractors therefore have experience of these methods, which can be applied to road construction.

The thickness and the reinforcement of concrete road slabs are usually chosen as a result of experience and experiment rather than on theoretical considerations. Neither the loads to be carried nor the strength of the foundation can be satisfactorily determined beforehand. Indeed it is quite impossible to foresee the weight of road vehicles and the loads that they may be called upon to carry in a few years' time. The only limit may well be the strengths of the roads and bridges, and, as in the case of aeroplane runways, the problem of the engineer will be to keep pace with the ever-increasing weight of the loads to be carried by roads. The need to restrict the weight of vehicles to the strength of roads and bridges should not be permitted to prevent the development of road vehicles, as has happened in the past. The strength of the foundation depends on the state of the soil when the road is laid and its behaviour under the varying conditions of moisture content and temperature to which it will be submitted by the vagaries of the weather. A knowledge of the present conditions of roads laid before the war, of their construction, of the conditions in which they were laid, of the maintenance that has been required for their upkeep, and particularly of the success achieved where efforts have been made to prevent the moisture content of the foundation being altered after the road is laid, is therefore of considerable value.

Useful additions were made to this knowledge in papers presented to the Pavings Development Group of the Cement & Concrete Association at a meeting held in London in November last. Amongst the papers was one by the secretary of the German Road Research Association in which information was given on the condition of the German motor roads (Autobahnen). Construction of these roads started in the year 1934, and by 1942 some 2400 miles had been completed. The original design allowed for two carriageways 24 ft. wide separated by a strip 13 ft. wide. Contrary to the view commonly held that these were primarily built for strategic military purposes, the author states that gradients and alignments were chosen mostly for the convenience and pleasure of the users of private cars, and that consequently some parts of the roads are not so suitable as they might be for heavy lorry traffic. The proportion of lorries to private cars is said to have doubled between the years 1936 and 1953. The allowable axle-load has been increased during this period from 7½ tons to 10 tons, and the speed of heavy traffic is also much greater, thus the stresses, particularly those due to impact, have increased considerably. For these reasons the present condition of different parts of the roads varies greatly between industrial and agricultural regions. It is, however, of interest to note that the German highway authority does not propose to make any important changes in the construction of extensions of these roads. The carriageways are still to be 24 ft. wide, but the central strip is to be increased to about 16 ft. 6 in. and parking spaces are to be provided along the sides of the carriageways. It is proposed that the parking spaces be of stabilized soil, not only for economy but also to discourage driving on them. The thickness of the carriageway was chosen in 1934 as 9 in. generally and 10 in. on high embankments, and these are to be the thicknesses of the new roads in spite of the increased weights of vehicles. More importance, however, is being given to the compaction of the foundation, and equipment, such as tamping plates and explosive rammers, has been developed for this purpose.

Many of the roads were constructed without reinforcement due to the shortage of steel; for the same reason dowels were not used in the later roads. It is proposed that the joints in new roads shall have dowels of 1-in. bars, and in a length of about three miles recently laid mesh reinforcement weighing 3·6 lb. per square yard was used. In this road the slab is 9 in. thick, a 7-in. layer being placed first, then the reinforcement, and finally a surface layer of 2 in. The concrete contained 540 lb. of cement per cubic yard and the water-cement ratio was 0·45. In the older roads the distance between expansion joints varied between 33 ft. and 50 ft.; expansion joints in the new road are 100 ft. apart, with two construction joints between them. The dowels are about ⅝ in. diameter and the joints were formed by sawing through the hardened concrete. This method of forming joints is considered to be most satisfactory as it ensures straight edges, a constant width and a greater strength of the concrete along the edges of a joint than is obtained by the usual methods.

Another paper presented to the meeting was a record of a survey of 190 miles of concrete roads in the United Kingdom. Many of these roads are up to forty years old and it is notable that, although the maintenance costs varied considerably as the roads were in both urban and rural areas, the average cost of maintenance of all the roads for which figures were available was stated to be only about two-thirds of a penny per square yard per year.

Prismatic Roof Slabs with Small Angular Change.

By A. J. ASHDOWN, A.M.I.Struct.E.

THE thin-slab prismatic structures dealt with in "The Design of Prismatic Structures" * have slabs inclined to one another at an angle of at least 30 deg. If the slabs have a much smaller angular change the elastic deformations at the junctions should be considered. The relative deformations of the junctions affect the cross bending moments over the junctions and consequently the loads transferred to the junctions, hence the longitudinal stresses and bending moments are altered. In the following analysis no account is taken of deformation due to compression in the direction tangential to the plane of the slabs in the cross section, or to deformation due to shear.

From the formula $\frac{T_0}{a_A} + 2T_1\left(\frac{1}{a_A} + \frac{1}{a_B}\right) + \frac{T_2}{a_B} - \frac{1}{2}\left(\frac{M_A}{Z_A} + \frac{M_B}{Z_B}\right) = 0$, the values of T are transposed in terms of the unknown stresses f, and to these are added the co-planar stresses due to the cross bending moments B over the junctions; as the formula now contains two unknown quantities, f and B, an additional equation is required, and is found from the equation of cross slopes due to the elastic deformation of the junctions in terms of the longitudinal stresses f and junction moments B. The shearing forces and stresses can be derived from the foregoing.

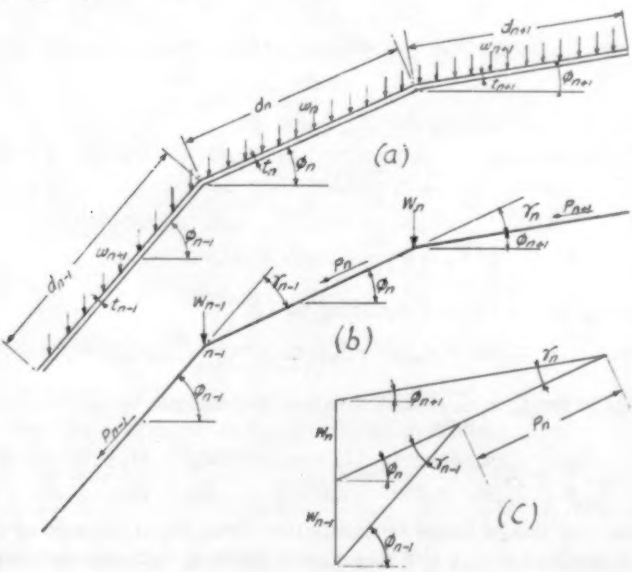


Fig. 1.

* References. "The Design of Prismatic Structures," by A. J. Ashdown; London, 1951. "Flachentragewerke," by Karl Girkman; Vienna, 1946. "Reinforced Concrete," by Suchnowski; Moscow, 1946. "Hipped Plate and Shell Roof Construction in Reinforced Concrete," by A. Krysztal; Journal of the Institution of Engineers of Australia, October and November, 1950.

In this analysis, the loading is assumed to be vertical only, and formulæ for the calculation of the co-planar forces P are derived on this assumption. Should the external forces be inclined the forces P may be derived graphically; or, if the external forces are normal to the slabs, the co-planar or axial forces P may be calculated by the formula given in the article by Professor H. Craemer in this journal for March, 1950.

DERIVATION OF THE FIRST EQUATION.—The resultants W at the junctions, assuming that the ends are hinged, are

$$W_{n-1} = \tfrac{1}{2}(w_{n-1}\,d_{n-1} + w_n d_n),\ W_n = \tfrac{1}{2}(w_n d_n + w_{n+1}d_{n+1}),\ \text{etc.,}$$

per strip of unit width. From *Figs.* 1(*a*), (*b*), and (*c*),

$$P_n = \frac{W_n \cos\phi_{n-1}}{\sin\gamma_n} - \frac{W_{n-1}\cos\phi_{n-1}}{\sin\gamma_{n-1}}.$$

Let $$\alpha_n = \frac{\cos\phi_n}{\sin\gamma_{n-1}} \quad\text{and}\quad \beta_n = \frac{\cos\phi_n}{\sin\gamma_n},$$

then the co-planar force $P_n = W_n\alpha_{n+1} - W_{n-1}\beta_{n-1}$. The force P_n produces a co-planar bending moment, $M_n = K_1P_nL^2$, along the length L of the slab about an axis normal to its surface, and at the centre for a freely-supported slab K_1 is $\frac{1}{8}$.

From formulæ (1) and (2) given in this journal for October, 1948,

$$f_n = \frac{-2T_{n-1} - 4T_n}{a_n} + \frac{M_n}{Z_n} \quad . \quad . \quad . \quad . \quad (1)$$

and

$$f_{n-1} = \frac{4T_{n-1} + 2T_n}{a_n} - \frac{M_n}{Z_n} \quad . \quad . \quad . \quad . \quad (2)$$

Let $\dfrac{M_n}{Z_n} = f_n^1$, and solving for T_{n-1} and T_n,

$$T_n = \frac{a_n}{6}(f_n^1 - 2f_n - f_{n-1}) \quad . \quad . \quad . \quad . \quad (3)$$

$$T_{n-1} = \frac{a_n}{6}(f_n^1 + f_n + 2f_{n-1}) \quad . \quad . \quad . \quad . \quad (4)$$

Transposing (4) to T_n and equating to (3),

$$a_nf_{n-1} + 2f_n(a_n + a_{n+1}) + f_{n+1}a_{n+1} = -f'_{n+1}a_{n+1} + f_n^1a_n.$$

Substituting for $f_n^1 = \dfrac{6M_n}{a_nd_n}$ and dividing throughout by 6,

$$f_{n-1}\frac{a_n}{6} + f_n\frac{(a_n + a_{n+1})}{3} + f_{n+1}\frac{a_{n+1}}{6} - \frac{M_n}{d_n} + \frac{M_{n+1}}{d_{n+1}} = 0 \quad . \quad . \quad (5)$$

This result can also be found by calculating moments of the area of the stress diagram (*Fig.* 2) about $n - 1$ and $n + 1$, and dividing each moment respectively by d_n and d_{n+1} gives the contribution to the longitudinal force equated to zero; similarly $\dfrac{\Delta M_n}{d_n}$ and $\dfrac{\Delta M_{n+1}}{d_{n+1}}$ may be calculated, and will also be the contribution to T_n from the moments on the slab.

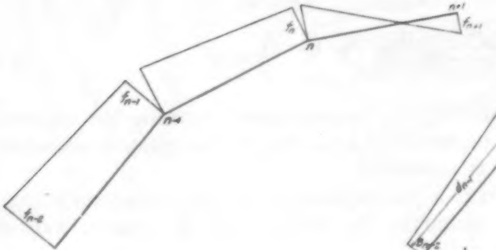


Fig. 2.

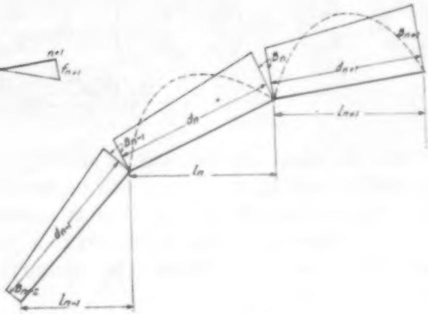


Fig. 3.

Formula (5) assumes that the joints are hinged but, due to the continuity and rigidity of the joints, bending moments B are produced at each joint, and these result in an additional external load ΔW, where

$$-\Delta W_n = \frac{B_n - B_{n+1}}{l_n} + \frac{B_n - B_{n+1}}{l_{n+1}} \quad . \quad . \quad . \quad (6)$$

An additional co-planar force and bending moment are also set up,

$$\Delta P_n = \Delta W_n \alpha_{n+1} - \Delta W_{n-1}\beta_{n-1} \quad . \quad . \quad . \quad . \quad (7)$$

$$\Delta M_n = K_1 \Delta P_n L^2 \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The additional contribution to formula (5) is therefore

$$\Delta T_n = -\frac{\Delta M_n}{d_n} + \frac{\Delta M_{n+1}}{d_{n+1}} \quad . \quad . \quad . \quad . \quad (9)$$

From (6), (7), and (8) the general expression for ΔT_n becomes

$$\Delta T_n = K_1 L^2 \Big\{ B_{n-2}\frac{1}{\sin\gamma_{n-1}d_{n-1}d_n} - B_{n-1}\left[\frac{1}{\sin\gamma_{n-1}d_{n-1}d_n} + \frac{\beta_{n-1}+\alpha_{n+1}}{l_n d_n} + \frac{1}{\sin\gamma_n d_n d_{n+1}}\right]$$
$$+ B_n\left[\frac{B_{n-1}+\alpha_{n+1}}{l_n d_n} + \frac{2}{\sin\gamma_n d_n d_{n+1}} + \frac{\beta_n + \alpha_{n+2}}{l_n d_{n+1}}\right] - B_{n+1}\left[\frac{1}{\sin\gamma_n d_n d_{n+1}} + \frac{\beta_n + \alpha_{n+2}}{l_{n+1}d_{n+1}}\right.$$
$$\left. + \frac{1}{\sin\gamma_{n+1}d_{n+1}d_{n+2}}\right] + B_{n+2}\frac{1}{\sin\gamma_{n+1}d_{n+1}d_{n+2}}\Big\} \quad . \quad . \quad (10)$$

or $\Delta T_n = K_1 L^2[C^n_{n-2}B_{n-2} + C^n_{n-1}B_{n-1} + C^n_n B_n + C^n_{n+1}B_{n+1} + C^n_{n+2}B_{n+2}]$, where C^n_{n-2} denotes the coefficient of B_{n-2}, etc., in equation (10).

Equation (5) with the addition of ΔT_n becomes

$$f_{n-1}\frac{a_n}{6} + f_n\frac{(a_n + a_{n+1})}{3} + f_{n+1}\frac{a_{n+1}}{6} - \frac{M_n}{d_n} + \frac{M_{n+1}}{d_{n+1}} + \Delta T_n = 0 \quad . \quad (11)$$

This expression contains the unknowns f and B; another equation is therefore required for their determination.

Derivation of the Second Equation.—The complete theorem of three moments expressing the equation of slopes and slope of deflection at any support n (*Fig.* 3) for a uniformly-distributed load and with sinking supports is

$$B_{n-1}\frac{d_n}{I_n} + 2B_n\left(\frac{d_n}{I_n} + \frac{d_{n+1}}{I_{n+1}}\right) + B_{n+1}\frac{d_{n+1}}{I_{n+1}} - 6E\left[\frac{\delta_n - \delta_{n-1}}{d_n} + \frac{\delta_n - \delta_{n+1}}{d_{n+1}}\right] + \frac{1}{4}\left(\frac{W_n d_n^2 l_n}{I_n} + \frac{W_{n+1} d_{n+1}^2 l_{n+1}}{I_{n+1}}\right) = 0 \quad . \quad . \quad . \quad (12)$$

Where the slabs are inclined at an angle γ_n to each other, forming the support, the deflections δ_n, δ_{n-1}, etc., will be modified according to the plane from which the deformation of the junction is measured.

The slope due to the deflection at n [the expression in square brackets in (12)] may be derived as follows. By geometry the distance to the neutral axis of slab n (*Fig.* 4) is

$$y_n = \frac{f_n d_n}{f_{n-1} - f_n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and from Hooke's law

$$M_n = \frac{f_n I_n}{y_n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Therefore at the central cross section of a slab with simply-supported ends and a uniformly-distributed load, $M_n = \frac{P_n L^2}{8}$ and the deflection is $\Delta_n = \frac{5}{384}\frac{P_n L^4}{EI_n}$; or substituting for M_n, $\Delta_n = \frac{5}{48}\frac{M_n L^2}{EI_n}$. Then, from (13) and (14),

$$\Delta_n = \frac{5}{48}\frac{L^2(f_{n-1} - f_n)}{d_n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

which is the co-planar deflection of slab n.

From the geometry of *Fig.* 5

$$\delta_n^n = \frac{\Delta_n \cos\gamma_n - \Delta_{n+1}}{\sin\gamma_n}, \text{ and } \delta_{n+1}^n = \frac{\Delta_n - \Delta_{n+1}\cos\gamma_n}{\sin\gamma_n}.$$

Then the expression in square brackets in (12) becomes

$$-6E\left[\frac{\delta_n^n - \delta_n^{n+1}}{d_n} + \frac{\delta_{n+1}^n - \delta_{n+1}^{n+1}}{d_{n+1}}\right],$$

where δ_n^n is the deflection of junction n relative to slab n, and δ_{n+1}^n is the deflection at n relative to slab $n+1$. Inserting values of Δ_n, etc., the expression becomes

$$+6E\left[\frac{\Delta_{n-1} - \Delta_n\cos\gamma_{n-1}}{d_n\sin\gamma_{n-1}} - \frac{\Delta_n\cos\gamma_n - \Delta_{n+1}}{d_n\sin\gamma_n} + \frac{\Delta_{n+1}\cos\gamma_{n+1} - \Delta_{n+2}}{d_{n+1}\sin\gamma_{n+1}} - \frac{\Delta_n - \Delta_{n+1}\cos\gamma_n}{d_{n+1}\sin\gamma_n}\right]$$

and, re-arranging,

$$+6E\left[\frac{\Delta_{n-1}}{d_n\sin\gamma_{n-1}} - \Delta_n\left(\frac{\cos\gamma_{n-1}}{d_n\sin\gamma_{n-1}} + \frac{\cos\gamma_n}{d_n\sin\gamma_n} + \frac{1}{d_{n+1}\sin\gamma_n}\right) + \Delta_{n+1}\left(\frac{1}{d_n\sin\gamma_n} + \frac{\cos\gamma_{n+1}}{d_{n+1}\sin\gamma_{n+1}} + \frac{\cos\gamma_n}{d_{n+1}\sin\gamma_n}\right) - \frac{\Delta_{n+2}}{d_{n+1}\sin\gamma_{n+1}}\right] \quad . \quad (16)$$

Fig. 4.

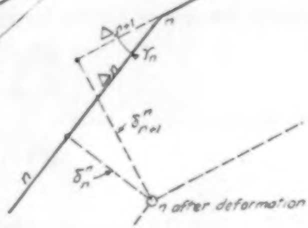


Fig. 5.

By putting values of Δ in terms of f, from (15) is obtained $+\frac{30}{48}L^2$ multiplied by values of f, the coefficients of which can be shown to be the same as those in (10).

By dividing the whole of the equation of three moments (12) by 6 and inserting $I_n = \frac{t_n^3}{12}$, the equation becomes

$$\frac{2B_{n-1}d_n}{t_n^3} + 4B_n\left(\frac{d_n}{t_n^3} + \frac{d_{n+1}}{t_{n+1}^3}\right) + 2B_{n+1}\frac{d_{n+1}}{t_{n+1}^3} + K_2L^2(C^n_{n-2}f_{n-2} + C^n_{n-1}f_{n-1}$$

$$+ C^n_nf_n + C^n_{n+1}f_{n+1} + C^n_{n+2}f_{n+2}) + \frac{1}{2}\left(\frac{w_nd_n^3\cos\phi_n}{t_n^3} + \frac{w_{n+1}d_{n+1}^3\cos\phi_{n+1}}{t_{n+1}^3}\right) = 0 \quad (17)$$

where at the centre of a span with freely-supported ends $K_2 = \frac{5}{48}$.

The foregoing expressions indicate the factors involved for an intermediate joint of a multiple-slab structure; attention is given later to conditions relating to the edge or tie-beam and to the ridge, if applicable. There will be as many equations as there are unknown stresses f and bending moments B. These equations are ill conditioned for solution by relaxation methods, and can be solved by successive elimination or by a matrix method.

Calculation of the Shearing Force.

The co-planar load at any point is $P_n + \Delta P_n$. Assuming the longitudinal distribution to be linear, the shearing force at point x from the end is

$$S_x = (P_n + \Delta P_n)\left(\frac{L}{2} - x\right) \quad . \quad . \quad . \quad . \quad (18)$$

The T-force can be obtained from (3) and (4) as follows.

$$T_n = \frac{a_n}{6}\left(\frac{M_n + \Delta M_n}{Z_n} - 2f_n - f_{n-1}\right) \quad . \quad . \quad . \quad (19)$$

and

$$T_{n-1} = \frac{a_n}{6}\left(\frac{M_n + \Delta M_n}{Z_n} + f_n + 2f_{n-1}\right) \quad . \quad . \quad . \quad (20)$$

where $\Delta M_n = K_1 L^2(\Delta W_n \alpha_{n+1} - \Delta W_{n-1}\beta_{n-1})$.

Calculation of the Shearing Stresses.

The shearing stress due to the force T along the top of the slab n is

$$q_n = \frac{4T_n}{Lt_n}\left(1 - \frac{2x}{L}\right) \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and along the bottom of the slab n is

$$q_{n-1} = \frac{4T_{n-1}}{Lt_n}\left(1 - \frac{2x}{L}\right) \quad . \quad . \quad . \quad . \quad (22)$$

where T_n and T_{n-1} are the values at the centre of the span.

The shearing stress due to the co-planar shearing force S_n at the middle of the slab n is $\frac{3}{2}\frac{S_n}{a_n}$. The resultant shearing stress at the middle (see the writer's book or this journal for July, 1950) is

$$q_m = \frac{3}{2}\frac{S_n}{a_n} - \tfrac{1}{4}(q_n + q_{n-1}) \quad . \quad . \quad . \quad . \quad (23)$$

Torsional Resistance of the Edge Slabs.

As the edge slabs vary in thickness and depth according to the conditions of the design, allowance should be made for torsional resistance. The bending moment B_x on the adjoining slab varies along its length according to the angle of twist θ, and will be least at the centre where θ is the greatest. The calculation for torsional rigidity can be only approximate since little is known of the value of the modulus of rigidity N of concrete, or of the effect of non-axial application of the twisting moment. At the ends the slab-loads will be supported longitudinally; hence the edge-slab will not have to resist any bending moments, but this will apply for only a short distance along the slab. Neglecting this effect the ends of the slabs tend to become completely fixed and the angle of twist becomes zero. It is assumed, therefore, that at the end $B_0 = -\frac{w_2 l_2^2}{12}$ (*Fig.* 6) and B_x has a parabolic variation between B_0 and B_c.

By St. Venant's method for a rectangle, and for a short length dx,

$$d\theta = \frac{B_x\, dx\, dx}{K_1 t d^3 N},$$

where K_1 is a constant depending on the ratio $\frac{t}{d}$, the values of which are:

$\frac{t}{d}$.	1·00	1·50	1·75	2·0	2·5	3·0	4·0	6·0	8·0	10·0	∞
K_1 .	0·141	0·196	0·214	0·229	0·249	0·263	0·281	0·299	0·307	0·313	0·333

The modulus of rigidity can be assumed to be 0·44 E_c.

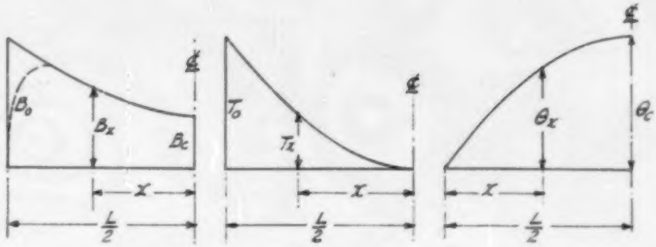


Fig. 6.

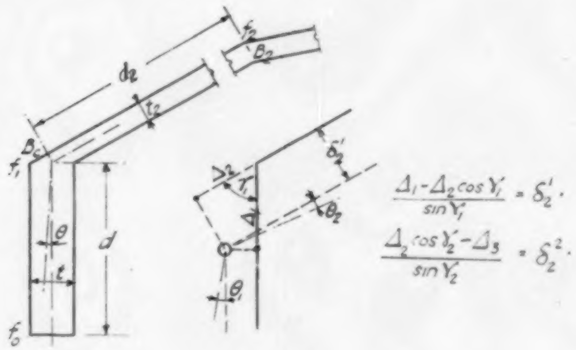


Fig. 7.

From *Fig.* 6 the bending moment at any point is $B_x = B_c + (B_0 - B_c)\frac{4x}{L^2}$. The torque, which will be zero at the centre and a maximum at the ends is, at any point,

$$T_x = \int B_x dx = \int B_c + (B_0 - B_c)\frac{4x^2}{L^2}dx = B_c x + (B_0 - B_c)\frac{4x^3}{3L^2},$$

and at the ends is

$$T_0 = \frac{L}{6}(2B_c + B_0) \quad . \quad . \quad . \quad . \quad . \quad (24)$$

Integrating over half the length for the angle of twist at the centre,

$$\theta_c = \frac{1}{K_1 t d^3 N}\Big[\frac{B_c x^2}{2} + (B_0 - B_c)\frac{x^4}{3L^2}\Big]_0^{\frac{L}{2}} = \frac{L^2}{48K_1 t d^3 N}(5\,B_c + B_0).$$

Assuming that $K_1 = 0{\cdot}281$ and $N = 0{\cdot}44\,E_c$,

$$\theta_c = \frac{L^2(5B_c + B_0)}{5{\cdot}94\,td^3E_c} \quad . \quad . \quad . \quad . \quad . \quad (25)$$

and $\theta_x = \theta_c \sin\frac{\pi x}{L}$ approximately, where x is measured from the end.

Equating the slopes at the centre, and ignoring for the moment deflections at the junction, $+\,\theta_c = -\,\theta_2$, and (*Fig.* 7)

$$+\frac{L^2(5B_c+B_0)}{5\cdot94td^3E_c}=-\frac{w_2d_2^3\cos\phi_1}{24E_cI_2}-\frac{B_2d_2}{3E_cI_2}-\frac{B_cd_2}{6E_cI_2},\text{ where } B_0=-\frac{w_2l_2^2}{12},$$

or substituting $\frac{d^3}{12}$ for I, cancelling E_c, and adding the normal deflections,

$$+\frac{L^2(5B_c+B_0)}{5\cdot94td^3}+\frac{w_2d_0^3\cos\phi_1}{2t_2^3}+\frac{4B_2d_2}{t_2^3}+\frac{2B_cd_2}{t_2^3}$$
$$+K_2L^2(C_0f_0+C_1f_1+C_2f_2+C_3f_3)=0 \quad . \quad (26)$$

Then the deflection term is $+6E[\delta_2^1-\delta_2^2]$, and from (15)

$$\varDelta_1=\frac{5}{48}\frac{L^2}{E_c}\frac{(f_0-f_1)}{d},\qquad \varDelta_2=\frac{5}{48}\frac{L^2}{E_c}\frac{(f_1-f_2)}{d_2},$$

and, by substitution,

$$\delta_2^1=+\frac{5}{48}\frac{L^2}{E_c}\left[\frac{(f_0-f_1)}{d\sin\gamma_1}-\frac{(f_1-f_2\cos\gamma_1}{d_2\sin\gamma_1}\right]$$
$$=-\frac{5}{48}\frac{L^2}{E_c}\left[\frac{f_0}{d\sin\gamma_1}-f_1\left(\frac{1}{d\sin\gamma_1}+\frac{\cos\gamma_1}{d_2\sin\gamma_1}\right)+\frac{f_2\cos\gamma_1}{d_2\sin\gamma_1}\right],$$

$$\delta_2^2=+\frac{5}{48}\frac{L^2}{E_c}\left[\frac{(f_1-f_2)\cos\gamma_2}{d_2\sin\gamma_2}-\frac{(f_2-f_3)}{d_3\sin\gamma_2}\right]$$
$$=-\frac{5}{48}\frac{L^2}{E_c}\left[\frac{f_1\cos\gamma_2}{d_2\sin\gamma_2}-f_2\left(\frac{\cos\gamma_2}{d_2\sin\gamma_2}+\frac{1}{d_3\sin\gamma_2}\right)+\frac{f_3}{d_3\sin\gamma_2}\right].$$

The deflection term becomes

$$+\frac{5}{48}\frac{L^2}{d_2}\left[\frac{f_0}{d\sin\gamma_1}-f_1\left\{\frac{1}{d\sin\gamma_1}+\frac{\cos\gamma_1}{d_2\sin\gamma_1}+\frac{\cos\gamma_2}{d_2\sin\gamma_2}\right\}\right.$$
$$\left.+f_2\left\{\frac{\cos\gamma_1}{d_2\sin\gamma_1}+\frac{\cos\gamma_2}{d_2\sin\gamma_2}+\frac{1}{d_3\sin\gamma_2}\right\}-\frac{f_3}{d_3\sin\gamma_2}\right]$$
$$=+K_2L^2(C_0f_0+C_1f_1+C_2f_2+C_3f_3)\quad . \quad . \quad . \quad (27)$$

For joint 2 the deflection term is

$$K_2L^2\left[\frac{f_0}{d_1d_2\sin\gamma_1}-f_1\left(\frac{1}{d_1d_2\sin\gamma_1}+\frac{\cos\gamma_1}{d_2^2\sin\gamma_1}+\frac{\cos\gamma_2}{d_2^2\sin\gamma_2}+\frac{1}{d_3d_2\sin\gamma_2}\right)\right.$$
$$+f_2\left(\frac{\cos\gamma_1}{d_2^2\sin\gamma_1}+\frac{\cos\gamma_2}{d_2^2\sin\gamma_2}+\frac{2}{d_2d_3\sin\gamma_2}+\frac{\cos\gamma_2}{d_3^2\sin\gamma_2}+\frac{\cos\gamma_3}{d_3^2\sin\gamma_3}+\frac{1}{d_2d_3\sin\gamma_3}\right)$$
$$\left.-f_3\left(\frac{1}{d_2d_3\sin\gamma_2}+\frac{\cos\gamma_2}{d_3^2\sin\gamma_2}+\frac{\cos\gamma_3}{d_3^2\sin\gamma_3}+\frac{1}{d_3d_2\sin\gamma_3}\right)\right]\quad . \quad . \quad . \quad (28)$$

Torsion on Supported Edge-Plates.

Where the edge-beams or tie-beams are supported but free to slide (which may be attained by supporting them on two layers of tarred paper) the formulæ will have to be adjusted. The conditions will be: (1) No bending moment M on the edge slab; (2) Uniform longitudinal stress f_1 throughout the edge slab; (3) No deflection of the edge slab, but an upward deflection of the adjoining slab relative to the next junction.

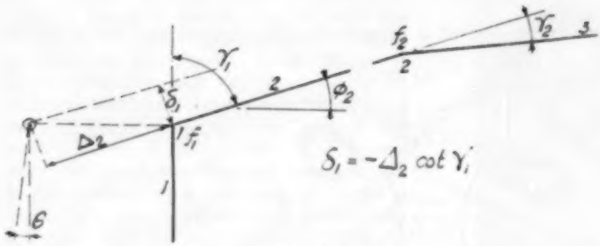


Fig. 8.

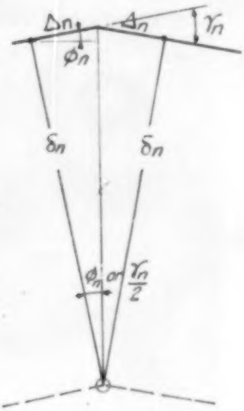


Fig. 9.

Referring to the formula before (16) the expression in square brackets in (12) for joint 1 (*Fig.* 8) becomes $+\,6E_e[-\,\Delta_2 \cot \gamma_1 - \delta_2^2]$

$$= -\,6E_e[\Delta_2 \cot \gamma_1 - \Delta_2 \cot \gamma_2 + \Delta_3 \operatorname{cosec} \gamma_2].$$

Then, by inserting the values for Δ, this is

$$-\frac{5}{48}\frac{L^2}{d_2}\left[f_1\frac{(\cot \gamma_1 - \cot \gamma_2)}{d_2} - f_2\left\{\frac{(\cot \gamma_1 - \cot \gamma_2}{d_2} - \frac{\operatorname{cosec} \gamma_2}{d_3}\right\} - f_3\frac{\operatorname{cosec} \gamma_2}{d_3}\right]$$

$$= -\,K_2L^2(f_1C_1 + f_2C_2 + f_3C_3).$$

At the centre, by equating the slope due to deflection to the angle of twist [see (26)],

$$\frac{L^2(5B_e+B_0)}{5{\cdot}94td^3} + \frac{w_2d_2^3 \cos \phi_1}{2t_2^3} + \frac{4B_2d_2}{t_2^3} + \frac{2B_ed_2}{t_2^3} - K_2L^2(f_1C_1+f_2C_2+f_3C_3) = 0 \quad . \quad (29)$$

For joint 2 the expression in square brackets in (12) becomes

$$-\,6E_e\left[\frac{\delta_2^2 + \Delta_2 \cot \gamma_1}{d_2} + \frac{\delta_3^2 - \delta_3^3}{d_3}\right],$$

and as $\delta_2^2 = \dfrac{\Delta_2 \cos \gamma_2 - \Delta_3}{\sin \gamma_2}$, $\delta_3^2 = \dfrac{\Delta_2 - \Delta_3 \cos \gamma_2}{\sin \gamma_2}$, and $\delta_3^3 = \dfrac{\Delta_3 \cos \gamma_3 - \Delta_4}{\sin \gamma_3}$, or if at a ridge, $\delta_3^3 = \Delta_3 \cot \dfrac{\gamma_3}{2}$, this expression becomes

$$-\frac{5}{48}L^2\left[f_1\left\{\frac{\cos \gamma_2}{d_2^2 \sin \gamma_2} + \frac{\cos \gamma_1}{d_2^2 \sin \gamma_1} + \frac{1}{d_2d_3 \sin \gamma_2}\right\}\right.$$

$$-\,f_2\left\{\frac{\cos \gamma_2}{d_2^2 \sin \gamma_2} + \frac{1}{d_2^2 \sin \gamma_2} + \frac{\cos \gamma_1}{d_2^2 \sin \gamma_1} + \frac{1}{d_2d_3 \sin \gamma_2} + \frac{\cos \gamma_2}{d_3^2 \sin \gamma_2} + \frac{\cos \gamma_3}{d_3^2 \sin \gamma_3}\right\}$$

$$\left. +\,f_3\left\{\frac{1}{d_2^2 \sin \gamma_2} + \frac{\cos \gamma_2}{d_3^2 \sin \gamma_2} + \frac{\cos \gamma_3}{d_3^2 \sin \gamma_3} + \frac{1}{d_4d_3 \sin \gamma_3}\right\} - \frac{f_4}{d_4d_3 \sin \gamma_3}\right]$$

$$= -\,K_2L^2(f_1C_1 + f_2C_2 + f_3C_3 + f_4C_4).$$

By equating slopes we have

$$\frac{2B_c d_2}{t_2^3} + 4B_2\left(\frac{d_2}{t_2^3} + \frac{d_3}{t_3^3}\right) + 2B_3\frac{d_3}{t_3^3} - K_2L^2(f_1C_1 + f_2C_2 + f_3C_3 + f_4C_4)$$
$$+ \frac{1}{2}\left(\frac{w_2 d_2^3 \cos\phi_2}{t_2^3} + \frac{w_3 d_3^3 \cos\phi_3}{t_3^3}\right) = 0 \quad . \quad . \quad (30)$$

If, however, joint 3 is the ridge of a symmetrically shaped and loaded roof this expression becomes for joint 2

$$-\frac{5}{48}L^2\Bigg[f_1\left(\frac{\cos\gamma_2}{d_2^2\sin\gamma_2} + \frac{\cos\gamma_1}{d_1^2\sin\gamma_1} + \frac{1}{d_2d_3\sin\gamma_2}\right) - f_2\left(\frac{\cos\gamma_2}{d_2^2\sin\gamma_2} + \frac{2}{d_2^2\sin\gamma_2} + \frac{\cos\gamma_1}{d_2^2\sin\gamma_1}\right.$$
$$\left. + \frac{\cos\gamma_2}{d_3^2\sin\gamma_2} + \frac{\cos\frac{\gamma_3}{2}}{d_3^2\sin\frac{\gamma_3}{2}}\right) + f_3\left(\frac{1}{d_2^2\sin\gamma_2} + \frac{\cos\gamma_2}{d_3^2\sin\gamma_2} + \frac{\cos\frac{\gamma_3}{2}}{d_3^2\sin\frac{\gamma_3}{2}}\right)\Bigg]$$
$$= -K_2L^2(f_1C_1 + f_2C_2 + f_3C_3) \quad . \quad . \quad . \quad (31)$$

The slope equation is then as (30) with f_4 omitted and different values of C_2 and C_3.

Deflection of the Ridge for Symmetrical Conditions.

If the cross section of the roof is divided into an even number of slabs with uniform loads, then by symmetry the deflection of the ridge (*Fig.* 9) $\delta_n^n = \Delta_n \cot\phi_n$, and at the lower end of the slab $\delta_n^{n-1} = \dfrac{\Delta_{n-1} - \Delta_n\cos\gamma_{n-1}}{\sin\gamma_{n-1}}$. The expression in square brackets in (12) becomes

$$-\frac{6E_c}{d_n}\left[\Delta_n\cot\phi_n - \left(\frac{\Delta_{n-1} - \Delta_n\cos\gamma_{n-1}}{\sin\gamma_{n-1}}\right)\right],$$

then by inserting values of f and re-arranging, this becomes

$$+\frac{5}{8}\frac{L^2}{d_n}\left[\frac{f_{n-2}}{d_{n-1}\sin\gamma_{n-1}} - f_{n-1}\left(\frac{1}{d_{n-1}\sin\gamma_{n-1}} + \frac{\cos\gamma_{n-1}}{d_n\sin\gamma_{n-1}} + \frac{\cot\phi_n}{d_n}\right)\right.$$
$$\left. + f_n\left(\frac{\cos\gamma_{n-1}}{d_n\sin\gamma_{n-1}} + \frac{\cot\phi_n}{d_n}\right)\right].$$

Dividing this by 6 the expression is then

$$+K_2L^2(f_{n-2}C_{n-2} + f_{n-1}C_{n-1} + f_nC_n) \quad . \quad . \quad . \quad (32)$$

For a roof with six slabs this may be written

$$\frac{w_3 d_3^3\cos\phi_3}{t_3^3} + \frac{4B_2d_3}{t_3^3} + \frac{8_1B_3d_3}{t_3^3} + K_2L^2(f_1C_1 + f_2C_2 + f_3C_3) \quad . \quad (33)$$

(*To be continued.*)

Colliery at Rothes, Scotland.

ROTHES COLLIERY is a new mine in Scotland. Each shaft accommodates four cages, and Koepe winders will be used. The main surface buildings will be the towers for the winders and the car hall, which are entirely of reinforced concrete.

Each tower is about 195 ft. high and 101 ft. by 70 ft. on plan at ground level, reducing to 101 ft. by 57 ft. at 80 ft. above ground; the top floor is 150 ft. above ground and carries electrical winding engines of 7500 h.p. and two Koepe wheels of 27 ft. diameter. The towers were designed for winding ropes 2⅞ in. diameter, having a breaking strength of about 380 tons. There are no internal columns, and the loads due to the winding engines, gears, and wheels are carried by beams to the walls.

The car circulation hall is 950 ft. long by 64 ft. wide by 40 ft. high; there are no internal columns and the towers straddle the hall so as not to interfere with the movement of the mine-cars. Other surface buildings, including the administration block, pithead baths, and workshops, will have reinforced concrete frames and floors and brick walls.

The work is being carried out by Messrs. Holland & Hannen and Cubitts (Scotland), Ltd., to the designs of the British Reinforced Concrete Engineering Co., Ltd., in conjunction with the Production Architect's Department of the Scottish Division of the National Coal Board.

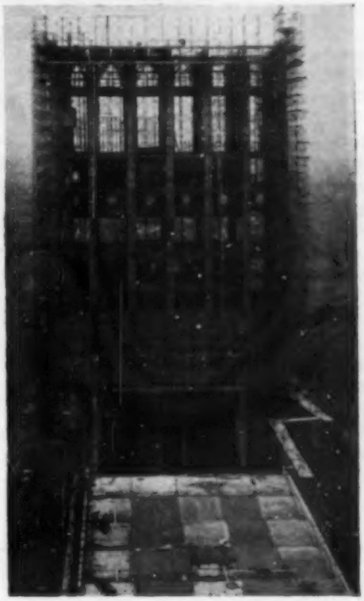


Fig. 1.—View of One Tower and Roof of Car Hall.

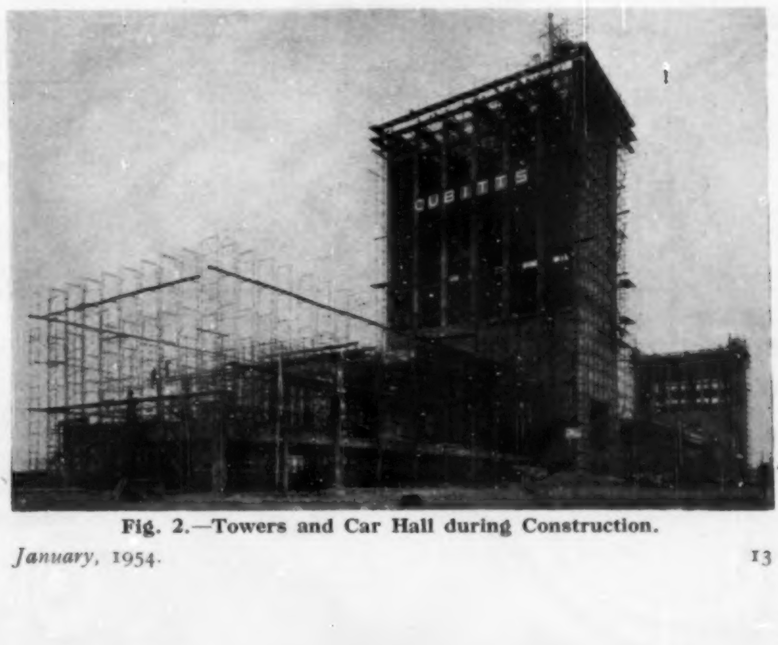


Fig. 2.—Towers and Car Hall during Construction.

Building at London Airport.

PRESTRESSED PRECAST FRAMES AND BEAMS.

THE new staff catering building for British European Airways at London Airport covers 26,300 sq. ft. and is one story high. Generally the main building consists of prestressed precast concrete members simply supported on columns, but the cafeteria and dining-room are spanned by fourteen prestressed precast frames at 12 ft. centres and with a span of 48 ft. centre to centre of the columns.

Construction.

The roof consists of 2-in. woodwool slabs covered with $\frac{1}{2}$ in. of cement mortar and bituminous felt. The woodwool slabs are supported by aluminium purlins at 2 ft. centres spanning between prestressed purlins which are supported by the main beams. The structure was designed for an inclusive dead and live load of 40 lb. per square foot.

The prestressed precast main beams and purlins were made on a long-line system. The purlins are 5 in. wide by $7\frac{1}{2}$ in. deep by 12 ft. long and rest on haunches on the main beams. To secure the purlins, holes were left in the main beams for continuity bars which passed under hoops protruding from the tops of the purlins and were concreted in situ (section 5–5, *Fig.* 1). The main beams are 1 ft. 3 in. deep by $7\frac{1}{2}$ in. wide by 24 ft. long. For economy and speed of construction, the haunches on the sides of the beams were cast on after the beams were prestressed. These beams are notched at

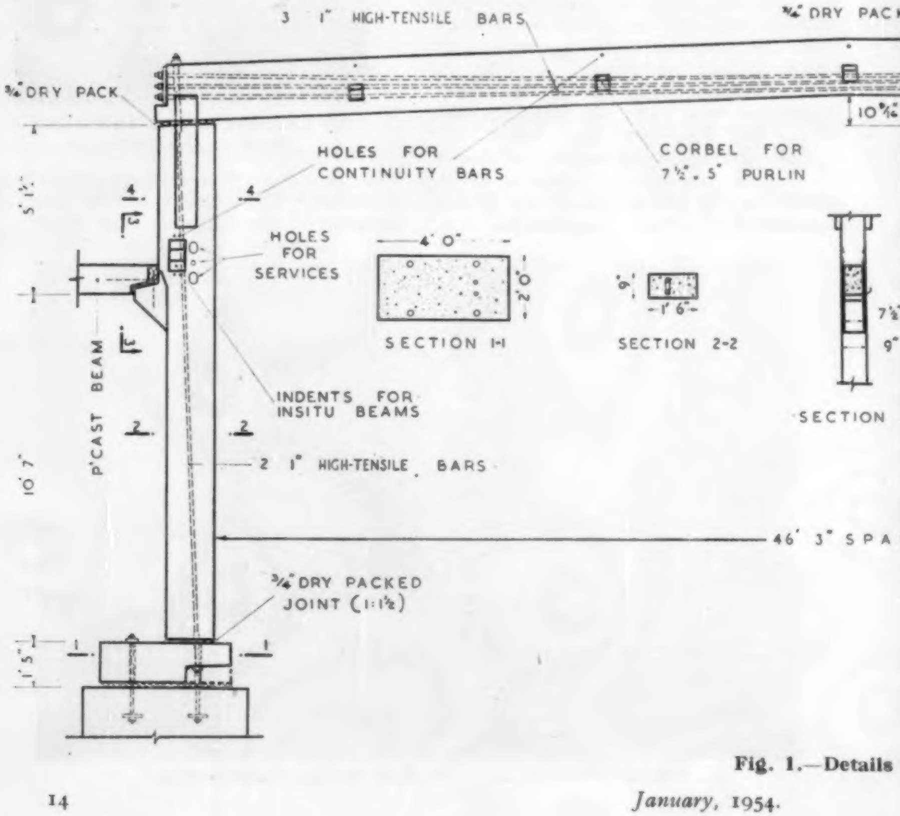


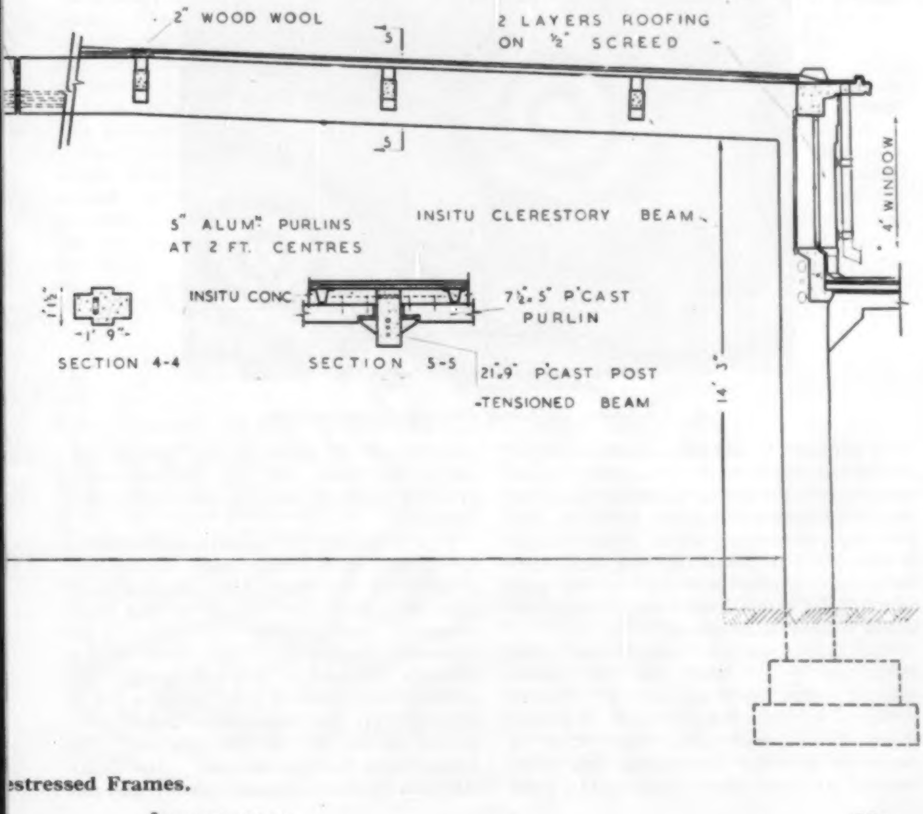
Fig. 1.—Details o

their ends and supported on splayed haunches on the reinforced concrete columns with a ½-in. "dry-packed" mortar joint. To keep the beams in position, dowel bars cast in the haunches pass through looped bars protruding horizontally from the ends of the beams, and the spaces between the ends of the columns and the beams are filled with in-situ concrete (*Fig.* 1). Where the main beams rest on the tops of the columns a hole 1½-in. diameter was made vertically through the end of the beam into which a dowel bar from the column was grouted from the top of the beam.

The reinforced concrete columns, 7½ in. wide by 12 in. deep and with haunches to support the main beams, were precast on the site. The bottoms of the columns are splayed at 67½ deg. on the face 7½ in. wide and rest on reinforced concrete footings 3 ft. long by 2 ft. wide. These footings were designed to resist the horizontal component of the thrust due to the splayed bottoms of the columns and are on mass concrete foundations. *Fig.* 2 shows part of the building before completion of the roof.

The Frames.

The frames (*Fig.* 3) are prestressed by high-tensile alloy-steel bars which were post-tensioned (*Fig.* 1). All the components of the frames were precast on the site and consisted of footings, columns, and main beams in halves. The footings, 4 ft. long by 2 ft. wide by 1 ft. 3 in. thick, were cast with a pocket formed on the underside to give access to the anchor-plate and nuts on the ends of the high-tensile bars. When prestressing was completed this pocket was filled with in-situ concrete. The cross-sectional dimensions of the columns below the adjacent



estressed Frames.

main roof are 1 ft. 6 in. by 9 in. increasing to 1 ft. 9 in. by 9 in. above this level, with a haunch on one side only to support the beams carrying the adjacent roof. The height from the top of the footing to the underside of the beams of the frames is 15 ft. 9 in. These beams, which are 1 ft. 9 in. deep by 9 in. wide by 49 ft. 10 in. long and have a rise of $10\frac{9}{16}$ in. at the centre, were cast in two parts and the brackets supporting the prestressed purlins were cast with the beams.

and was carried out simultaneously from both ends in the following order: (1) central bar, (2) top bar, (3) bottom bar. The initial jacking force for each bar was 33 tons, giving an extension of $2\frac{3}{8}$ in., but it was found necessary to increase the initial jacking force on the central bar by 2 tons to compensate for shortening when the other bars were tensioned. The initial upward deflection of the beams due to prestressing averaged $\frac{1}{4}$ in. and the average shortening was $\frac{3}{16}$ in. On

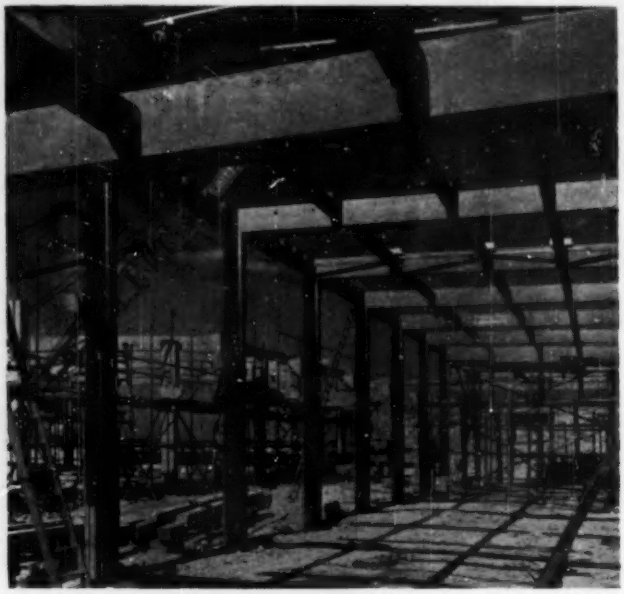


Fig. 2.—Main Building During Construction.

completion of stressing the spaces between the bars and the cavities were grouted through holes in the sides of the beams.

In addition to the reinforcement in the end-blocks, mild steel is provided in the beams and columns for handling purposes and to keep in position the $1\frac{1}{8}$-in. sheaths for the prestressing bars. The footing is reinforced to resist bending, and reinforcement is also provided in the part which acted as a cantilever during the initial stages of construction.

The halves of the main beams were assembled $\frac{3}{4}$ in. apart and the joints caulked with earth-moist $1\frac{1}{2}:1$ sand-cement mortar. Each beam contains three 1-in. prestressing bars with a parabolic profile. Tensioning was commenced 24 hours after caulking the joint

The sequence of operations following the prestressing of the main beams was as follows. (1) Reinforced concrete footings were cast and bolted to the mass concrete foundations. (2) Two 1-in. diameter prestressing bars were passed through the sheaths in a column and the column was hoisted into position on a footing. (3) The beams were hoisted and placed on top of the columns. (4) The frames were then prestressed. The joints between the footings and columns and the

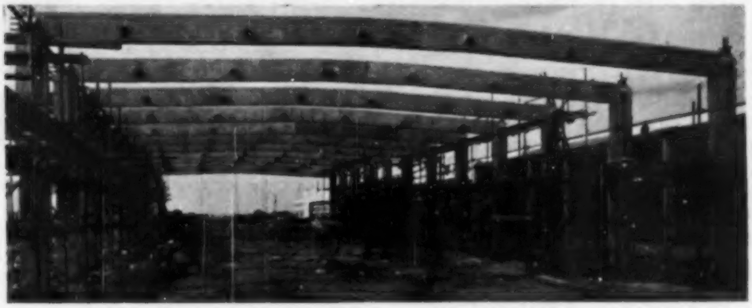


Fig. 3.—Prestressed Frames of Cafeteria and Dining Room.

columns and beams are $\frac{3}{4}$ in. wide and packed with 1 : $1\frac{1}{2}$ cement-sand mortar.

The tensioning of the bars in the columns to complete the prestressing of the frame was carried out simultaneously from both ends and at the top of the beams. The first bar was tensioned to 10 tons and the second bar to 20 tons; the first bar was then tensioned to 33 tons and the second to 33 tons, giving a total extension of each bar of $\frac{7}{8}$ in. The bars were grouted in the cavities.

The concrete for the frames had a works cube strength of 6250 lb. per square inch at fourteen days. The maximum design compressive stress was 2500 lb. per square inch under full working conditions. The initial stress in the bars was 42 tons per square inch, which reduced to 35 tons per square inch under full working conditions.

Five of the frames were completely assembled with purlins and eaves-beams together with the in-situ clerestory beams, and the central frame was loaded. The deflection at mid-span under the design load was 0·433 in., and 0·668 in. with $1\frac{1}{2}$ times the live load.

The architect is Mr. C. S. White, F.R.I.B.A., of Messrs. Ramsey, Murray & White. Messrs. Scott and Wilson, MM.I.C.E., are the consulting engineers. The main contractors are Messrs. Holland & Hannen and Cubitts, Ltd., and the Concrete Development Co., Ltd., supplied the prestressed precast beams and purlins. The frames were prestressed by the Lee-McCall system.

New Cement Works.

New cement works costing about £5,000,000 are to be built by the Associated Portland Cement Manufacturers, Ltd., one near Cauldon in Staffordshire and one near Westbury in Wiltshire. The capacity of each works will be 175,000 tons a year. It is hoped that the works will be in production in two-and-a-half years. The cost is nearly five times the pre-war cost of similar works.

Because of the suitability of the raw materials, manufacture at Cauldon will be by the dry process, which requires less fuel than the wet process; this will be the first dry-process cement works in this country.

During the year 1953 nearly half a million tons of cement were imported from Europe, and it was also necessary slightly to reduce exports. It is expected that, together with increases in output that are being obtained at existing works and with other plans of expansion, these new works will enable all the home requirements and also the requirements of the Empire to be supplied. With a view to affecting as little as possible the amenities of the neighbourhoods of the new works, the Company has had the advice of a landscape architect, trees have been planted at Westbury, and further planting will be undertaken.

Water Tower at Glasgow.

A WATER TOWER (*Fig.* 1), with a capacity of 500,000 gallons, was recently completed and forms part of a new distribution system to serve a large new housing estate at Cranhill, on the outskirts of Glasgow.

The tank is 75 ft. square externally and has an overall height of 20 ft. 9 in. The walls are 15 in. thick for a height of 14 ft. and 9 in. thick for a height of 6 ft. 9 in. The floor consists of a slab 2 ft. thick resting on 16 columns spaced at 20 ft. centres in two directions. The columns are circular, 3 ft. diameter, and have a clear height of 64 ft. 3 in. They rest on separate bases 15 ft. square by 2 ft. 6 in. thick. The flared heads of the columns are 7 ft. 6 in. diameter and the floor spans as a flat slab between them. *Figs.* 2 and 3 show the main details.

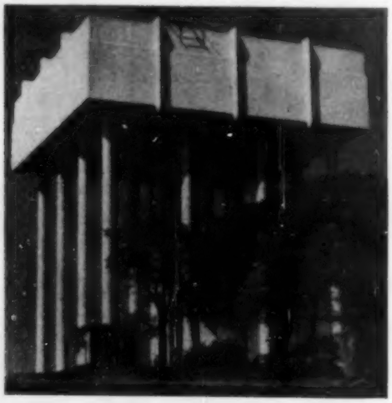


Fig. 1.

The tank is divided internally into two L-shaped compartments by a wall 15 in. thick. The maximum height of water is 16 ft. 6 in., with 12 in. of freeboard. Access to the tank is by a central tower, 13 ft. 4 in. square externally, with 8-in. reinforced concrete walls. The tower is lighted by continuous vertical windows on each side extending to almost its full height. A lift and an emergency ladder are provided inside the tower. All the piping is arranged inside the tower, the valve-control platform being level with the underside of the floor slab. The roof is a flat slab 9 in. thick, supported on sixteen columns of 15 in. diameter directly above the main columns, and a penthouse giving access to the roof projects 11 ft. 8 in. above it.

The construction joints were rendered watertight by a rubber water-stop. This is a 9-in. wide strip of rubber cast into both sides of the joint, its shape forming a key into the concrete, and it has proved an effective seal. The joints were covered externally by precast concrete nosing members which are used as a feature to relieve the otherwise monotonous surface.

The total weight of mild steel reinforcement used was 160 tons, and the total volume of concrete 47,150 cu. ft. The work was started in May, 1951, and the tower was put into use in June, 1953.

The tower was built for the Corporation of Glasgow Water Department. The consulting engineers, who acted in collaboration with the City Water Engineer, Mr. Stanley D. Canvin, B.Sc.(Eng.), M.Inst.C.E., were Messrs. F. A. Macdonald & Partners. The contractors were Messrs. Drummond, Lithgow & Co., Ltd.

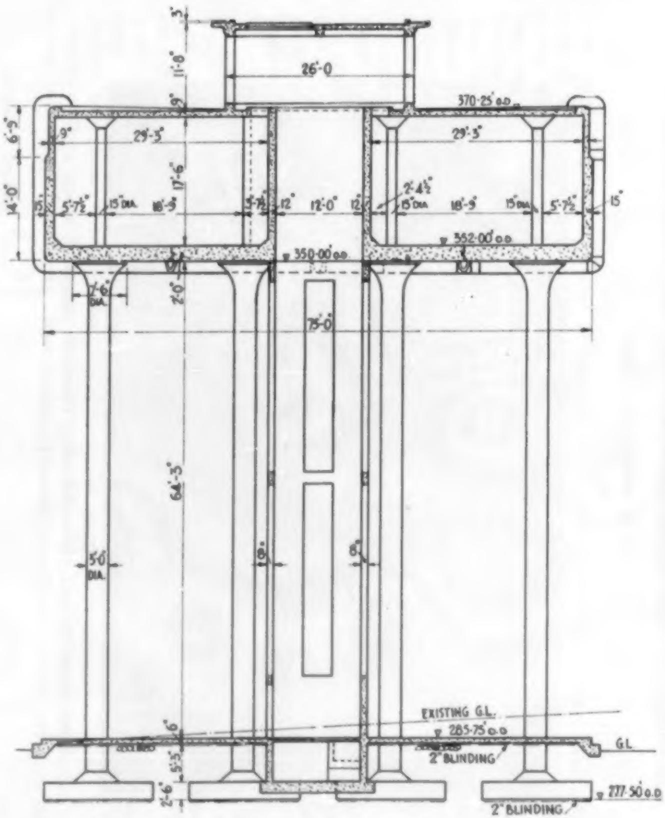


Fig. 2.—Cross Section.

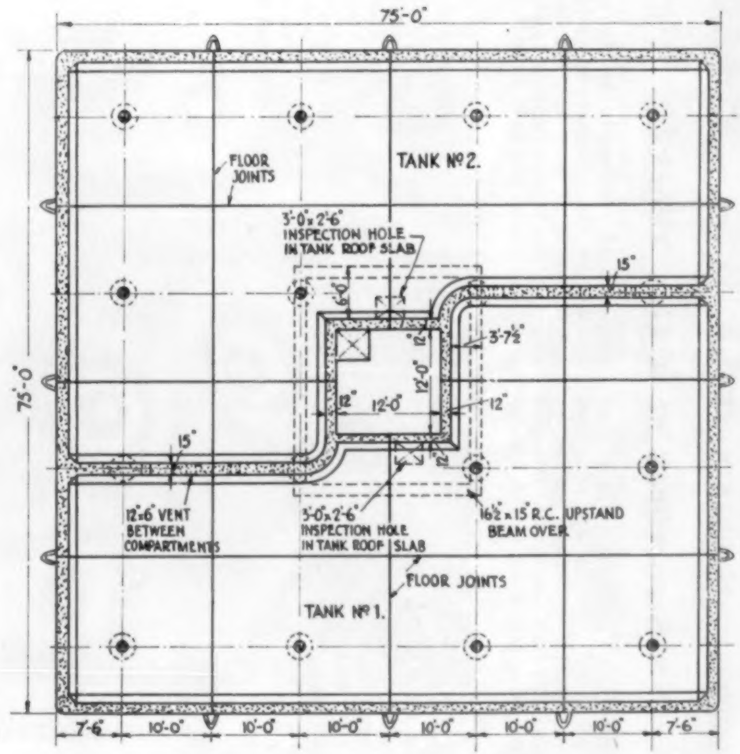
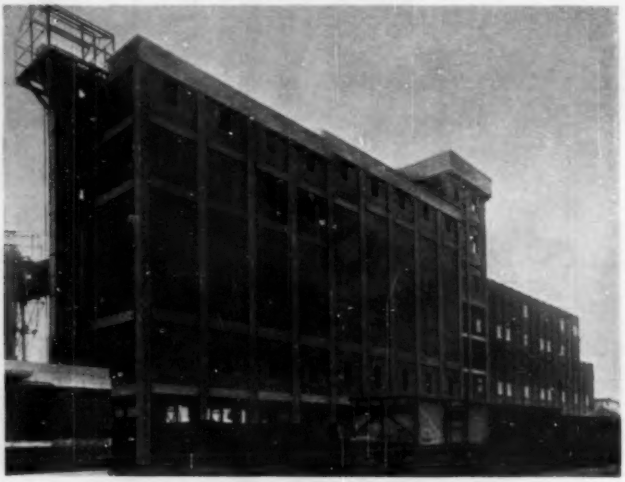


Fig. 3.—Sectional Plan of Tank

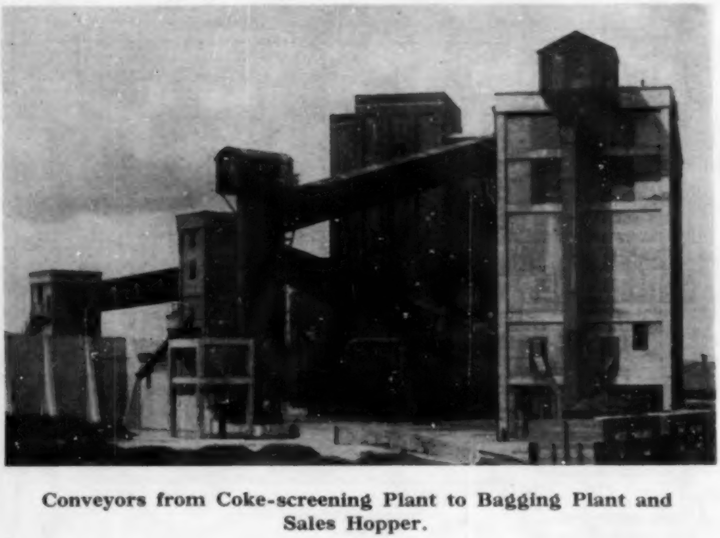
Water Tower at Glasgow. (*See page* 18.)

Structures at a Gas Works.

THE new Swan Village gas works at West Bromwich will provide an additional 11½ million cubic feet of gas per day for the West Midlands Gas Board. Many of the structures and most of the foundations are of reinforced concrete. The building for the coke-screening plant is 148 ft. long by 37 ft. wide by 98 ft. high and is on 129 precast reinforced concrete piles 14 in. square and 30 ft. to 40 ft. long.



Coke-screening Plant.



Conveyors from Coke-screening Plant to Bagging Plant and Sales Hopper.

The gasholder has a capacity of 5 million cu. ft.; the reinforced concrete tank is 211 ft. in diameter and 12 ft. deep. Other structures built in reinforced concrete include a coke-bagging platform and hopper which is 56 ft. high and a sales-hopper 48 ft. high. Steel shuttering was used throughout except for some special work.

The consultants for the reinforced concrete work are Messrs. Henry Hale & Partners, and the general contractors Messrs. Robert M. Douglas (Contractors), Ltd.

Factory at Nuneaton.

THE new fettling shop (*Fig.* 1) recently built for Sterling Metals, Ltd., at Nuneaton, is 330 ft. long by 120 ft. wide and the walls are 27 ft. high to the top of the parapet. The roof comprises pairs of three-pinned reinforced concrete frames spanning 60 ft., supported along the outer walls by columns at 15 ft. centres and along the centre of the factory on columns at 30 ft. centres with alternate frames on beams supported by the columns. The roof is covered with aluminium alloy sheets at a pitch of 22½ deg. secured to precast concrete purlins. There are four strips of continuous patent glazing extending nearly the full length of the building. The outer walls are of no-fines concrete 12 in. thick to a height of 6 ft. above floor level, and were cast in shutters clamped to the main columns. The no-fines concrete is rendered with aerated concrete applied by compressed air. From a precast concrete sill on the walls rise mullions which form three windows in each bay. These mullions are fixed at eaves level to a composite parapet and boundary-gutter which spans from column to column. Glazing is fixed directly to the mullions and horizontal glazing bars.

The frames were precast in halves, each half comprising a vertical member 9 ft. 6 in. high and a rafter about 30 ft. long. At the ridge the ends of the rafters are in a "crown boss" which transmits the thrust from the members while allowing rotational movement. The feet of the frames are carried, at a height of 16 ft. above floor level, in half-round roller bearings at the bottom of channels in the upper part of the main columns. The frames are simply supported on the columns and there is sufficient clearance for them to deflect outwards at eaves level while imposing an oblique thrust upon the columns at the roller bearings only.

The columns act as vertical cantilevers and the tensile reinforcement is near the inner face. As the stress in the columns is primarily that due to a bending moment which is greatest at the footings and zero at the level of bearings of the frames, the columns are battered externally. The columns were precast and erected in two parts, continuity being obtained by reinforcement passing from the foundations through channels in both parts and concreted in situ.

Along the centre of the building alternate pairs of frames are supported on beams spanning between the columns. These beams, of inverted tee-shape, were precast and are connected across the columns, for the full length of the building, by reinforcement in recesses formed in the haunched ends of the beams; after the beams were placed in position the recesses were filled with concrete. *Fig.* 2 is a cross section through part of the building and *Fig.* 3 shows the structure partly completed.

Although the frame is of precast members throughout there are no bolted

Fig. 1.

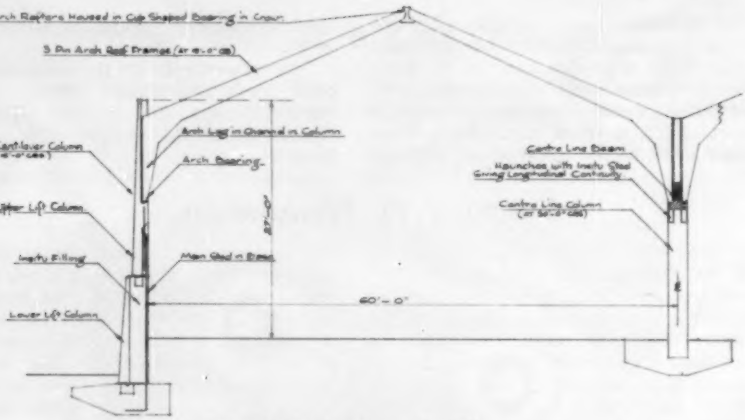


Fig. 2.—Part Cross Section.

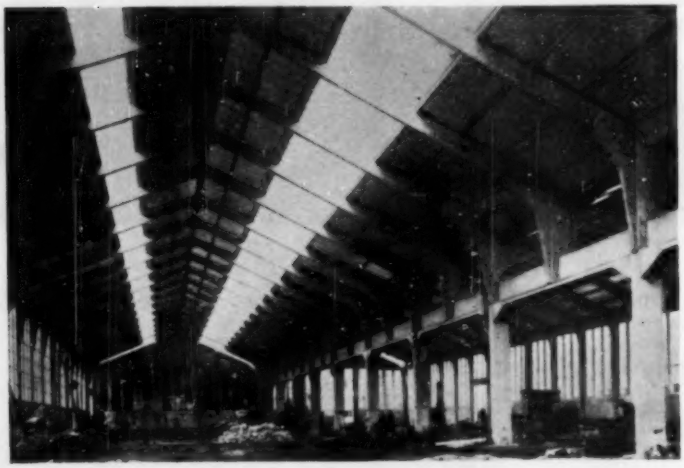


Fig. 3.—Interior during Construction.

connections, steel gusset-plates, or scarfed joints. Each member imposes a direct thrust upon the adjacent member or is made continuous with it by bars bonded in in-situ concrete. The precast members are designed in accordance with B.S. Code of Practice No. 114, and all the reinforcement has a cover of at least 1 in.

The construction is statically determinate, and the resultant of the weight of the columns, walls, and superstructure and the thrust due to the frame is considerably nearer to the centres of the columns than it would be if only thrust and loads due to the frame were considered; even so, bases rather longer and projecting farther from the building than is usual are required. It is, however, claimed that the method leads to economy in reinforcement, and the simple connections between members result in speed of erection which more than compensates for the larger bases. The structure was erected in fifteen weeks and an average of sixteen men were employed.

The structure was designed and erected by Beecham Buildings, Ltd., who also made the precast members.

A Garage in London.

CURVED BEAMS SPANNING 194 FT.

THE garage shown in *Figs.* 1 and 2, at Stockwell, London, has been built for London Transport Executive and will accommodate 200 buses. The main building is 392 ft. by 194 ft. and has an uninterrupted floor area of 73,350 sq. ft. Along one side of this building, but structurally independent, are workshops and stores about 300 ft. long by 76 ft. wide. Offices, staff rooms, and a canteen are in a separate two-story building.

The main building (*Fig.* 3) consists of ten two-hinged reinforced concrete frames at 42-ft. centres with curved beams spanning 194 ft. Between the beams and forming the roof are reinforced concrete

Fig. 1.

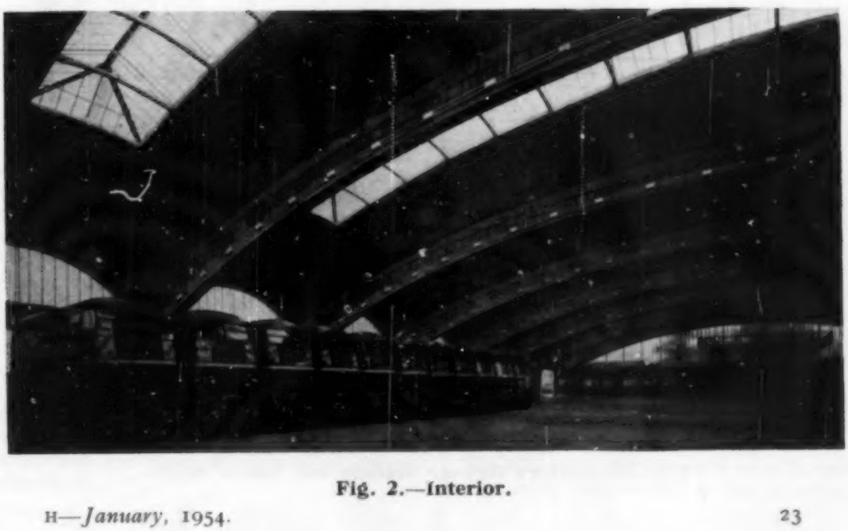


Fig. 2.—Interior.

slabs curved in two directions, following the curvature of the beams in one direction and having a radius of 26 ft. 9 in. between the beams. In the middle of each bay is a roof-light 140 ft. by 14 ft., so that for the greater part of their length the slabs are cantilevered about 14 ft. on each side of the beams. Connecting the curved slabs and passing under the roof-lights at 10-ft. centres are ribs 6 in. wide by 8 in. deep to reduce torsion in the main beams due to unsymmetrical loads on the slabs.

The main beams of the intermediate frames are 2 ft. 2 in. wide by 7 ft. deep at the crown, increasing to 10 ft. 6 in. at the haunches. The two end beams are the same depth as the intermediate beams but are 8 ft. wide. These beams are hollow and comprise an inner side 2 ft. 2 in. thick connected by 12-in. slabs at top and bottom to an outer side 1 ft. 6 in. wide. This cross-section is required to resist horizontal thrusts due to the live loads.

The columns of all the frames decrease from 10 ft. 6 in. by 2 ft. 2 in. at the top to 6 ft. by 2 ft. 2 in. at floor level; below floor level they are widened to 7 ft. 6 in. by 8 ft. to increase their lateral stability, as the only longitudinal ties between the

Fig. 4.—Reinforcement for a Hinge.

frames are H-shaped beams 16 ft. above floor level. These beams extend around the four sides of the building and carry a 9-in. cast-iron rainwater pipe, a 6-in. sprinkler main, compressed-air and water ring-mains and electrical conduits; the main entrance doors and the doors to the repair shops are also supported by these beams. Expansion joints are provided in these beams in the length of the garage;

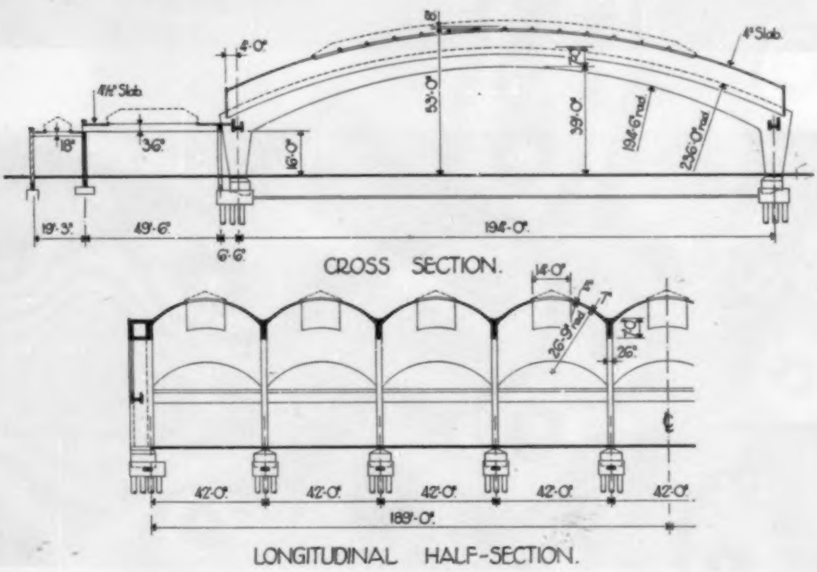


Fig. 3.—Sections through Garage and Repair Shop.

on the side adjoining the repair shop the joints are formed by a freely-supported beam carried on brackets on the columns of the two central frames; on the opposite side the joints are at the points of contraflexure of the beam between the two central frames.

The columns are supported on piled foundations and are hinged at their junctions with the pile caps. The reinforcement for a hinge is shown in *Figs.* 4 and 5. The horizontal thrust is resisted by ties connecting opposite pile caps, the ties comprising continuous welded loops of 1½-in. bars coated with bitumen and encased in concrete. There are 22 bars in the ties connecting the intermediate columns where the thrust is 260 tons and 28 bars resisting a thrust of 340 tons in the ties connecting the end columns. The piles are the bored type and are 1 ft. 7 in. diameter with a safe load of 60 tons each. The foundations for the intermediate columns, where the load is about 400 tons, consist of eight piles except for the columns adjoining the repair shop where there are nine piles. For the end frames there are eleven piles in the foundations adjoining the repair shop and ten piles elsewhere.

The reinforcement of an intermediate frame and curved slab is shown in *Figs.* 5 and 6, and in *Fig.* 7 is shown the reinforcement of a column. Because of the comparatively small cross-section of the members the main bars, which were supplied in lengths of 60 ft., were welded. The welds, which are of the single-V type with a cover plate, are as far as possible from the points of greatest bending moment and staggered in each layer of bars so as to reduce any weakness resulting from a possible faulty weld.

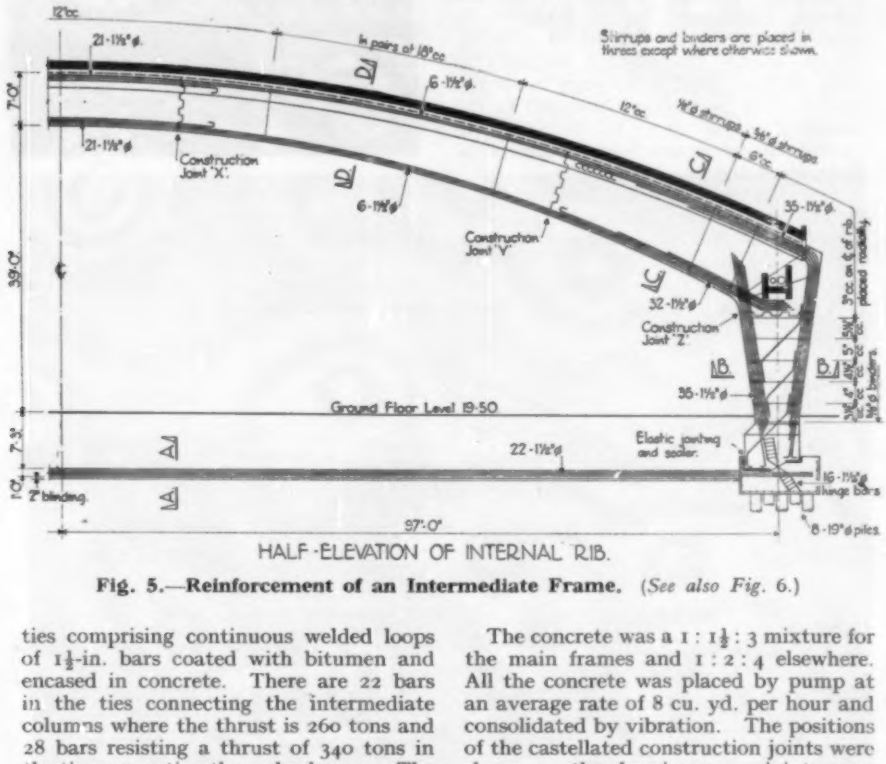


Fig. 5.—Reinforcement of an Intermediate Frame. (*See also Fig.* 6.)

The concrete was a 1 : 1½ : 3 mixture for the main frames and 1 : 2 : 4 elsewhere. All the concrete was placed by pump at an average rate of 8 cu. yd. per hour and consolidated by vibration. The positions of the castellated construction joints were shown on the drawings; no joints were made in the vertical members of the frames between the hinges and the haunch at the junction with the cross-member. The floors of the garage and repair shops are 8 in. thick laid on 6 in. of hardcore on blinding and finished with 1½ in. of granolithic. The floors were reinforced with a single layer of steel mesh.

The allowable stresses were 1000 lb. per square inch compression in the concrete

and 18,000 lb. per square inch tension in the steel, except for the ties where the stress was 16,000 lb. per square inch. The design was in accordance with the by-laws of the London County Council. The shuttering for the curved beams comprised sheet-steel panels with timber make-up pieces for the sides and a timber soffit. Timber shutters were used for the curved slabs in the roof. The shutters for the ribs were supported by tubular steel scaffold tubes, of which 35,000 ft. were needed for one rib.

Artificial lighting is provided by continuous fluorescent lamps attached to each side of the curved beams (*Fig.* 2). In the garage the average intensity of light at floor level is between three and four lumens per square foot and in the servicing areas this is increased to 13 lumens per square foot by additional fluorescent lamps.

The architects were Messrs. Adie Button & Partners, in association with Mr. Thomas Bilbow, F.R.I.B.A., Architect of London Transport Executive. The consulting engineer for the reinforced concrete work was Mr. A. E. Beer, A.C.G.I., M.I.Struct.E. Messrs. Wilson Lovatt & Sons, Ltd., were the general contractors and the Cementation Co., Ltd., carried out the foundation work.

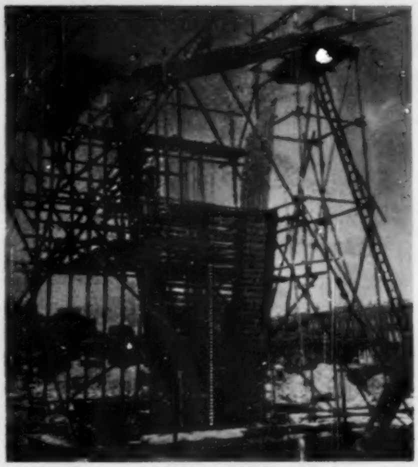


Fig. 7.—Reinforcement for a Column.

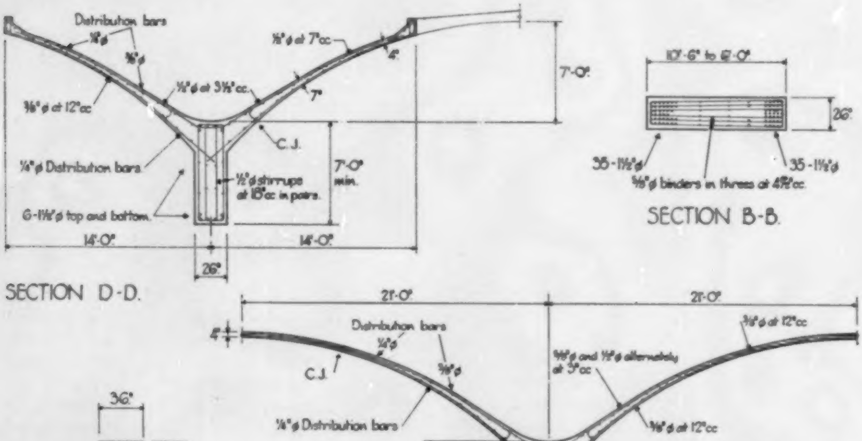


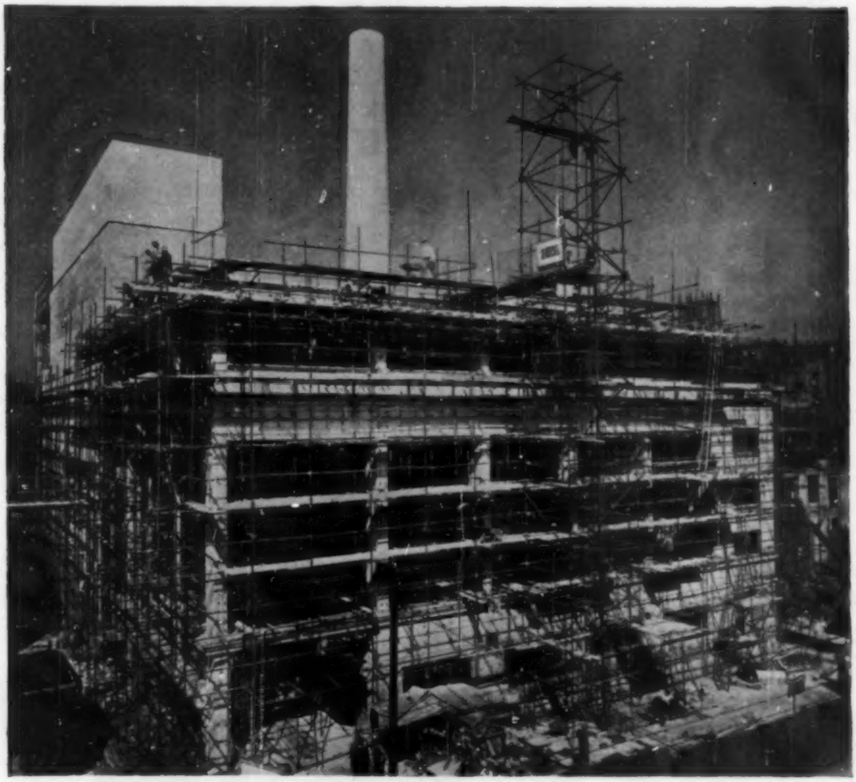
Fig. 6.—Cross Sections of an Intermediate Frame and Cantilever Slabs.
(*See also Fig.* 5.)

Power Station, Nottingham.

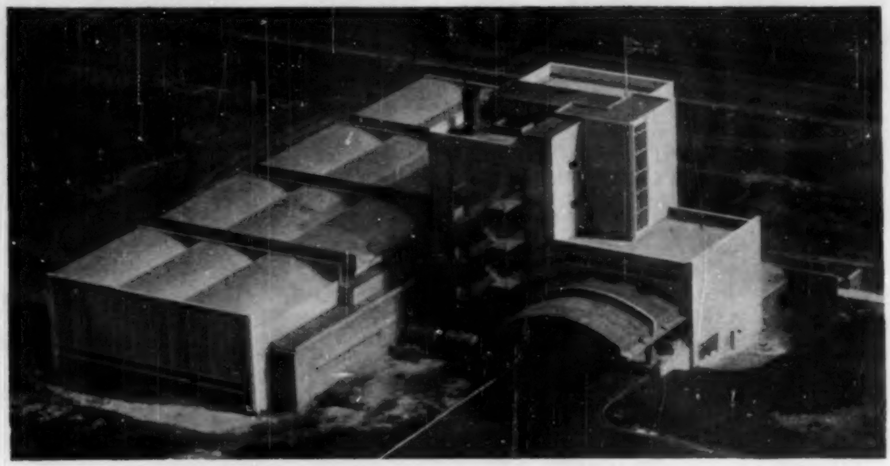
THIS power house has recently been constructed in London Road, Nottingham, for Boots Pure Drug Co., Ltd. It consists of a boiler house 94 ft. by 67 ft., a turbine house 98 ft. by 44 ft. divided by a corridor 15 ft. wide from buildings containing 3 bunkers each of 250 tons capacity, a gravity-bucket pit, an ash-hoist pit, settling tanks, mess rooms, offices, and chimney, all of which are in reinforced concrete. The site was a canal wharf which had been filled in, and all the foundations were taken down to Trent gravel about 14 ft. below ground level.

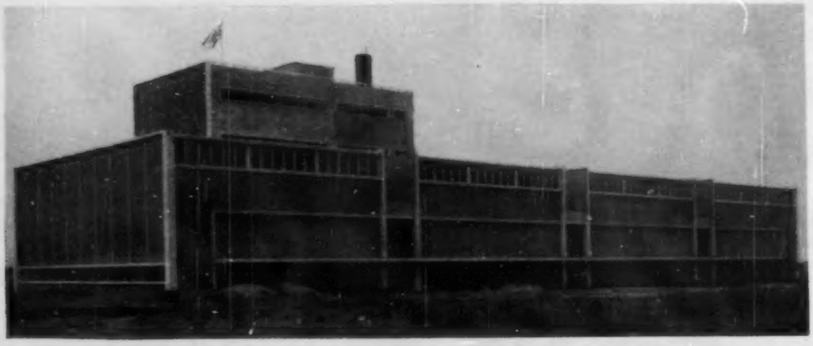
The chimney, the top of which is 149 ft. above ground, tapers from 14 ft. 3 in. to 9 ft. 9 in. overall, and the wall varies in thickness from 9 in. to 6 in. The brick lining was built in 4 ft. lifts and used as internal shuttering. The bunkers are about 28 ft. by 20 ft. by 30 ft. deep and are lined with gunite; the roof over the bunkers is 90 ft. above ground. The bottom of the gravity-bucket pit is 20 ft. below ground level. Provision has been made for future extension.

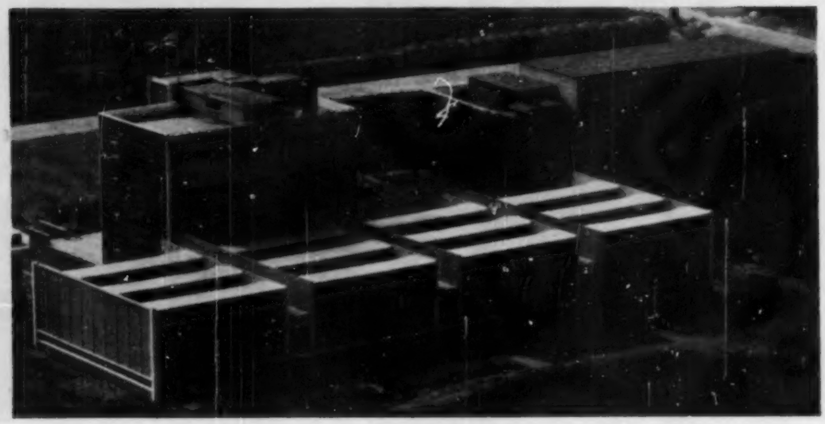
The structures were planned by the owners' Architect's Department, and the reinforced concrete design is by the British Reinforced Concrete Engineering Co., Ltd. Messrs. W. J. Simms, Sons & Cooke, Ltd., were the main contractors.



Power House during Construction.







Figs. 1 to 3.—A Factory with Shell Roofs.

(See facing page.)

A Factory with Shell Roofs.

THE factory at Westwood, Margate, for the Klinger Manufacturing Co., Ltd., consists of one department for knitting, one for rough finishing, and an office block. The buildings are separated by expansion joints. *Figs.* 1 to 4 are views of the factory and *Fig.* 5 is a block plan.

The knitting department is a two-story building 210 ft. long by 72 ft. wide. The basement is used as a cycle store and the upper floor as a knitting room. The roof comprises north-light barrel vaults arranged in four bays with three vaults to each bay; the bays are separated by a flat slab 9 ft. wide.

The vaults in each bay span 46 ft. between stiffening beams, which in turn span 72 ft. between the external columns. The north lights are 4 ft. high and are double-glazed, the windows being set in precast concrete frames. The absence of internal columns permits the whole floor area to be utilised for the knitting machines. On the east and west elevations the stiffening beams are extended downwards to the ground floor to form wall beams 22 ft. 6 in. high which span 72 ft. and carry part of the first floor in addition to the shells. Windows under these walls extend the full width of the building. Protruding fins are used to form a decorative feature.

The upper floor is of mushroom construction and is designed for an imposed load of 2 cwt. per square foot. The slab is 8 in. thick and is supported by columns 12 in. square at 15 ft. 4 in. centres longitudinally and 14 ft. 5 in. centres transversely in bays corresponding to the spans of the shell roofs; the bays are separated by 6-in. slabs 9 ft. wide. The knitting machines subject the floor to considerable vibration. Along one side of the building the slab projects 3 ft. 4 in. to form an escape balcony and is rebated to allow for future extensions. Longitudinal and cross sections through the building and details of the stiffening beams are shown in *Fig.* 7.

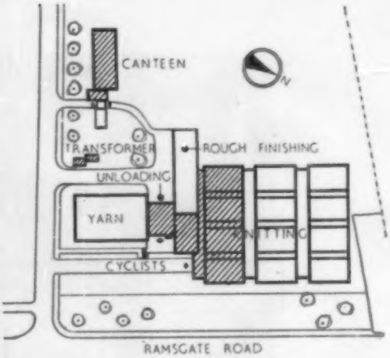


Fig. 5.—Block Plan.

Rough Finishing Block.

This is a five-story building 72 ft. long by 42 ft. wide with provision along one of the shorter sides for an extension of 65 ft. The floors are 6 in. thick and are supported by a reinforced concrete frame. One of the shorter walls is of reinforced

Fig. 4.

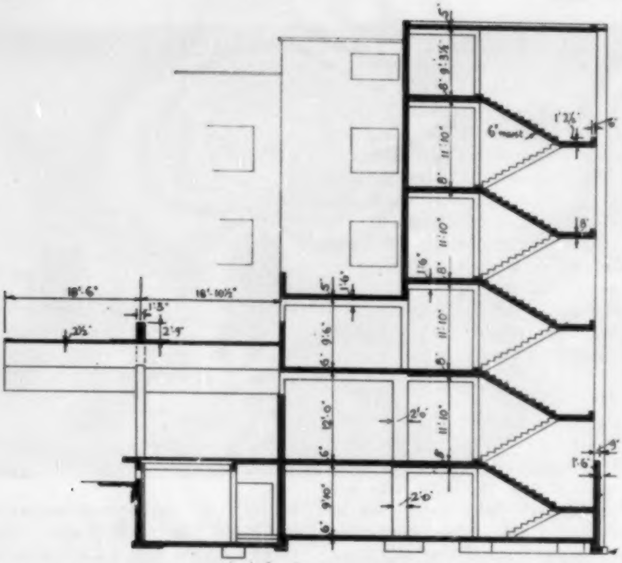
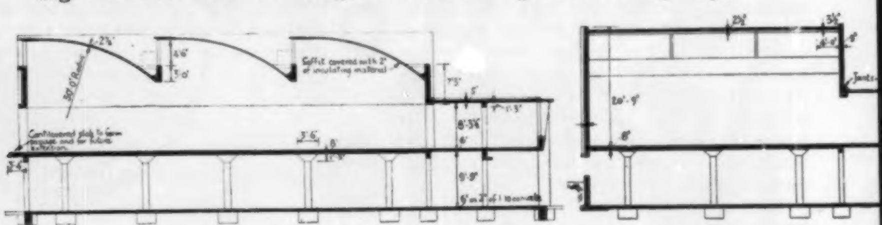


Fig. 6.—Cross Section through Office Building and Loading Bay.



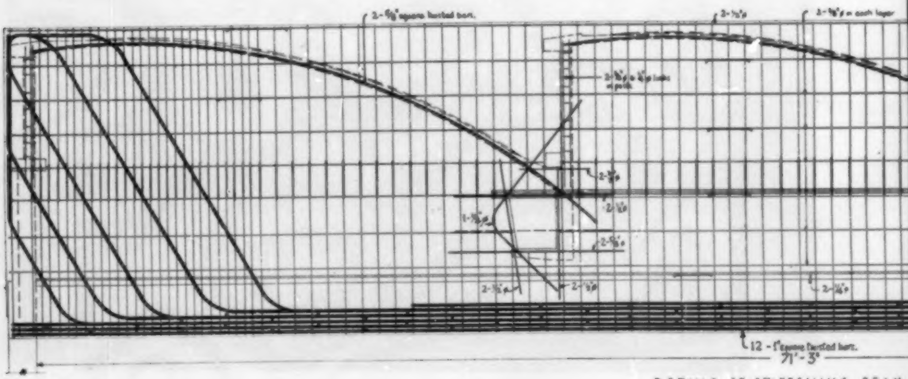


Fig. 7.—Details of

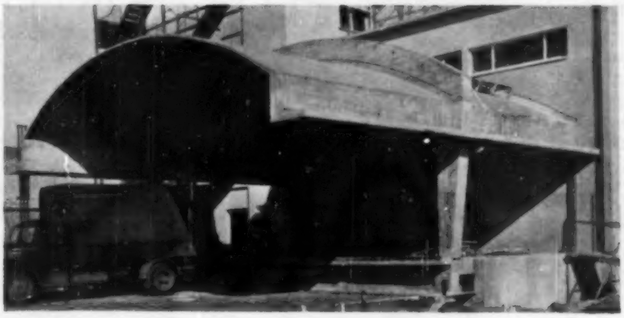
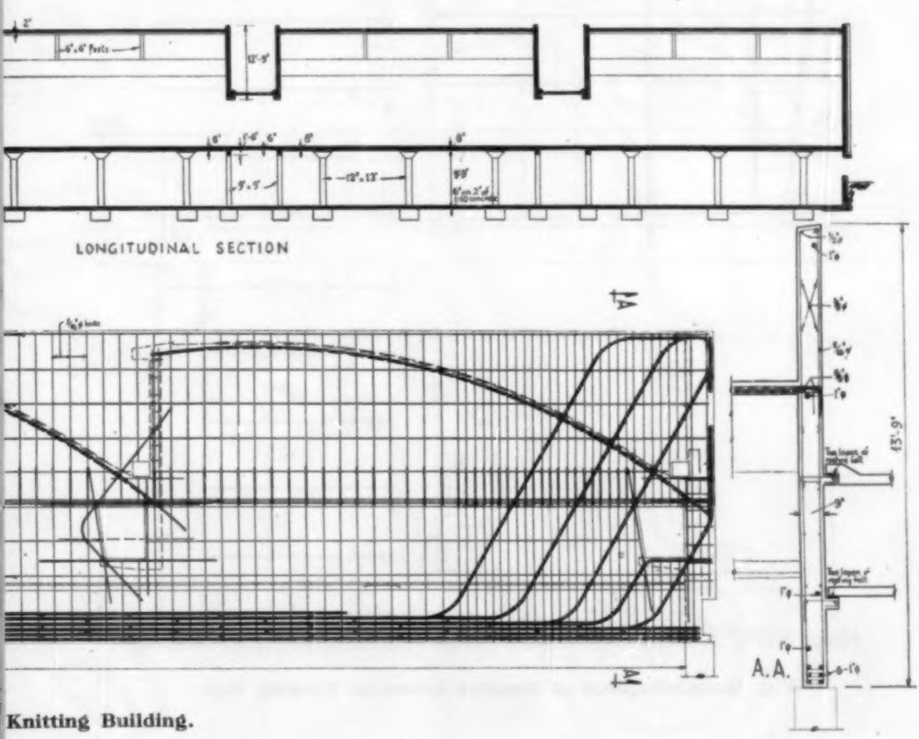


Fig. 8.—The Loading Bay.



Knitting Building.

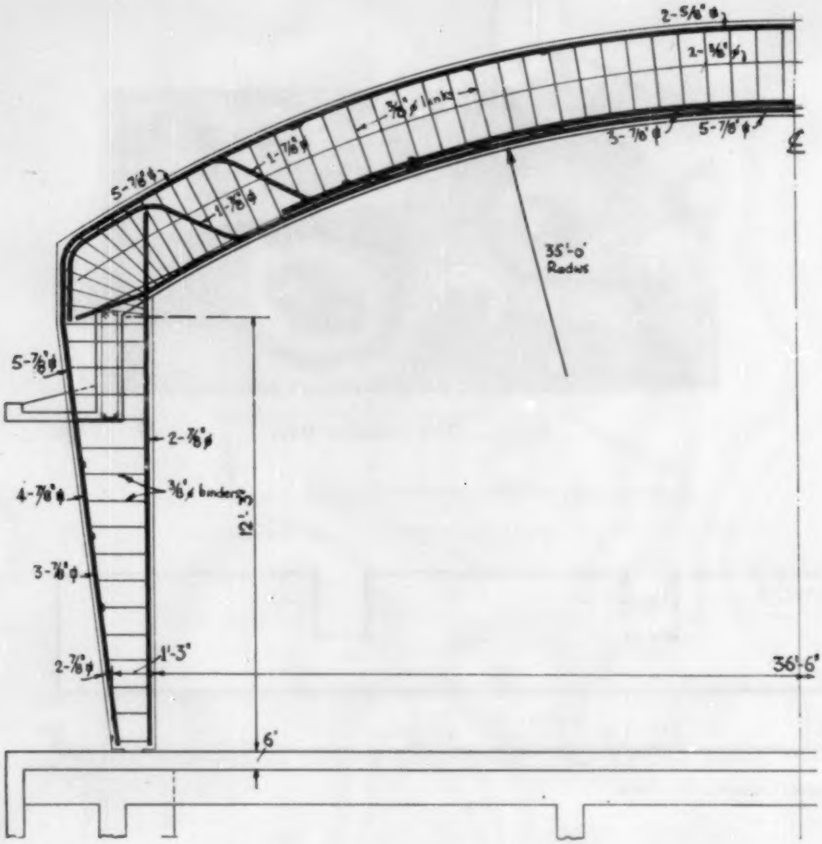


Fig. 9.—Details of Frame in Loading Bay.

Fig. 10.—Cross Section Through Frame in Loading Bay.

concrete 6 in. thick and faced with tiles. All the floors are designed for a superimposed load of 100 lb. per square foot. A part plan and cross sections are shown in *Fig.* 11.

Office Block.

The office and entrance block is a three-story reinforced concrete framed structure. At the rear is a loading bay covered by a barrel-vault roof. The barrel is supported at one end on the 6-in. reinforced concrete wall of the office building. The vault spans 19 ft. on to a reinforced concrete frame, beyond which it cantilevers 18 ft. to provide a space unimpeded by columns. The chord width of the barrel is 39 ft. and the curved slab, $2\frac{1}{2}$ in. thick, is pierced near its junction with the main building by three roof lights of 4 ft. internal diameter ; a cross section is shown in *Fig.* 6. Details of the frame supporting the vault are given in *Figs.* 9 and 10. *Fig.* 8 shows the loading bay.

The foundations of all the buildings are designed for a ground pressure of 4 tons per square foot, the subsoil being chalk.

The architect was Mr. Harald Weinreich, A.R.I.B.A., and the structural consultant was Dr. K. Hajnal-Konyi. The work was carried out by Messrs. Rice & Son, Ltd.

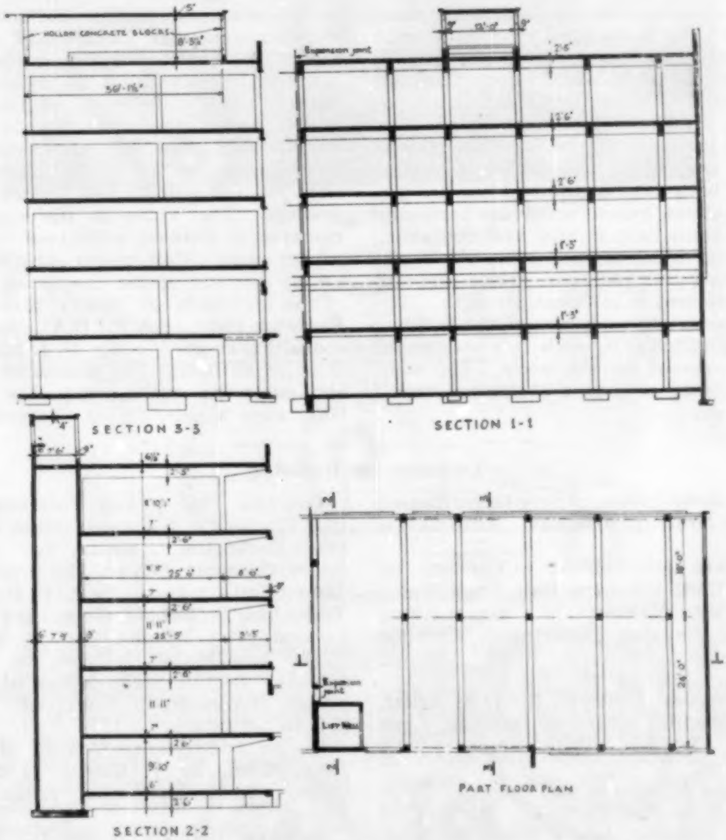


Fig. 11.—Details of Rough-finishing Building.

Composite Precast and In-situ Farm Building.

THE cowhouse shown partly completed above is 67 ft. long by 33 ft. 8 in. wide. The structural frame consists of 8-in. by 8½-in. precast columns supporting prestressed precast rafters 6 in. square, on which are prestressed slabs 1½ in. thick which are covered with a reinforced concrete topping 1½ in. thick. Extending along both sides of the building are precast gutters, behind which are horizontal edge-beams cast in situ and containing prestressing cables, in sheaths, which were tensioned after the 1½-in. in-situ roof-slab had attained a sufficient strength. The edge-beams on each side of the building are connected at the ends by a prestressed tie supported on the walls. The completed roof acts as a "stressed skin" structure.

The prestressed rafters and roof slabs were made on a long-line system. On one side of the roof the rafters are shaped to a triangular frame for a north-light. At the ends of the rafters are steel connecting plates so that the rafters may be bolted to the columns and together at the ridge. The columns are at 9 ft. 7 in. centres and were grouted into pockets formed in the footings. The whole of the structural concrete is finished with two coats of rubber paint. Cast-in-situ grain hoppers are at one end of the cowhouse.

The architects are Messrs. Stillman & Eastwick-Field, AA.R.I.B.A., and the consulting engineer is Mr. F. J. Samuely, B.Sc., A.M.I.C.E. The contractors, who also made the prestressed precast members, were Messrs. David Chaston, Ltd.

Lectures on Building.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

Modern Developments in Concrete, by R. C. Blyth. Central Hall, Cross Street, Aldershot. January 12. 7 p.m. And at the Building Department, Croydon Polytechnic, Selhurst Road, London, S.E.25. January 28. 7 p.m.

Prestressed Concrete, by J. S. Arlett. Hammersmith School of Building, Lime Grove, London, W.12. January 14. 7.15 p.m.

British Standards and Codes of Practice, by Patrick Cutbush. Ministry of Works Building, Ashley Street, Birmingham, 5. January 19. 7.15 p.m. And at the Lecture Theatre, Technical College, Bolton. January 27. 7.15 p.m.

Concrete Placing and Formwork, by L. J. Murdock. Technical College, Northgate, Darlington. January 19. 7 p.m. Kirby Grammar School, Middlesbrough. January 20. 7 p.m. By A. B. Harman. Tottenham Technical College, High Road, London, N.15. January 20. 7.15 p.m.

The New Model By-Laws, by R. A. Simons. Lecture Hall, College of Technology, Byrom Street, Liverpool. January 20. 7.15 p.m.

Design and Quality Control of Concrete Mixes, by J. Runcie. Technical College, West Hartlepool. January 26. 7 p.m.

Building Methods in the U.S.A., by W. R. Turner. Technical College, Queen Street South, Huddersfield. January 27. 7.15 p.m.

Prestressed Bridge for a Railway and Coal Conveyors.

THE bridge shown in *Fig.* 1 has a clear span of 74 ft. and carries a light railway and two conveyor belts over a road near Calverton, Nottinghamshire. It was built for the East Midlands Division of the National Coal Board to connect the winding-shafts of a colliery with a coal-preparation plant. Separate overhead conveyors were not permitted and the conveyors had to be within the bridge, for which purpose a minimum depth of 5 ft. was required between the upper deck and the floor. A headroom of 16 ft. 6 in. was required under the bridge, and the least possible gradient for the railway was necessary. These conditions are satisfied by the dimensions shown in *Fig.* 2, and, to cause the least interruption during construction to traffic using the road, much of the work was precast.

Fig. 1.

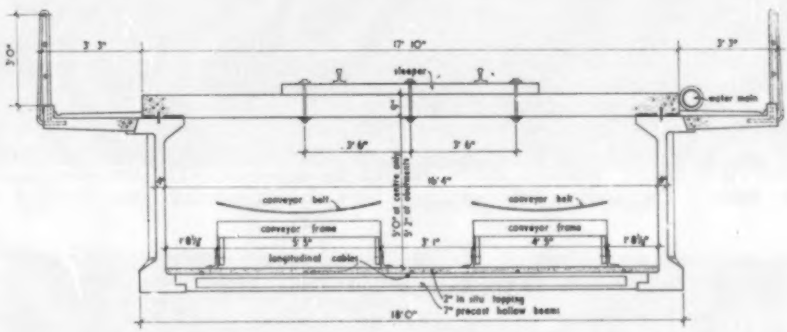


Fig. 2.—Cross Section.

The bridge comprises two prestressed precast beams at 16 ft. 8 in. centres supporting on their top flange a 9-in. prestressed in-situ deck carrying the railway and on their bottom flanges a prestressed precast floor carrying the conveyors. Footpaths 3 ft. 3 in. wide are cantilevered from the top flanges. The beams are supported on Freyssinet hinges allowing rotation and horizontal movement at one end and rotation only at the other end. The abutments are of plain concrete faced with stone, and are on the shaft-pillar of the colliery. The bridge was designed in accordance with British Standard No. 153 to carry two Diesel locomotives each weighing 42 tons and a loaded truck weighing 20 tons. The speed of trains is restricted to ten miles per hour. The coal conveyor weighs 135 lb. per linear foot and the refuse conveyor 115 lb. per linear foot. The maximum load on the

Fig. 3.—Erecting the Girders.

coal conveyor is 4·46 tons and on the refuse conveyor 3·8 tons.

Construction.

The two main beams are 77 ft. long by 5 ft. 9 in. deep and have a camber of 2 in. The webs are 4 in. thick at the centre increasing to 7 in. at the ends. Each beam was cast in three parts, the ends weighing $5\frac{1}{2}$ tons each and the central part $8\frac{1}{4}$ tons. The beams were precast at a works in Manchester and transported by road to the site, where they were lifted on to the abutments and timber towers leaving a space of about $\frac{3}{4}$ in. between the end and central parts (*Fig.* 3). After the beams were aligned, six cables each containing twelve 0·2-in. wires were placed through ducts in each beam. The spaces between the parts of each beam were filled with a stiff 1 : 1 cement-sand mortar. After the joints had hardened the cables were tensioned from each end simultaneously and the ducts grouted.

The conveyor-floor was then constructed. This consists of transverse precast hollow beams with inverted precast channel-beams at 4 ft. 6 in. centres to accommodate transverse cables (*Fig.* 4). The cables are in plastic sheaths and were laid in the inverted channels which were then filled with concrete. These cables are anchored in the lower flanges of the longitudinal beams. Over the bearings at each end, in-situ concrete was placed between the beams to form anchorages for longitudinal cables laid on the floor of the conveyor. The transverse cables were then tensioned, thus forming the

Fig. 4.—Construction of the Conveyor Floor.

longitudinal beams and the conveyor-floor into a U-shaped beam. Five cables were placed longitudinally on the conveyor-floor and the whole floor covered with 2 in. of concrete. These cables, which are in sheaths and anchored in the in-situ prestressed concrete at each end of the bridge, were then tensioned.

The in-situ top slab was cast next. This is anchored to the beams by dowels projecting from the upper flanges and is supported over the width of the web of each beam only by placing on each side of the top flange of each beam pieces of compressible board with a space of 4 in. between them. This was done to avoid transmitting torsional moments to the girders. The transverse cables, in plastic sheaths, are at 8 in. centres; the cables are looped so that both ends of each cable are anchored on the same side of the bridge, and cables are anchored alternately on opposite sides of the bridge (*Fig.* 5). The wires at the loops were bare and separated to bond with the concrete. Tensioning was carried out from both ends simultaneously.

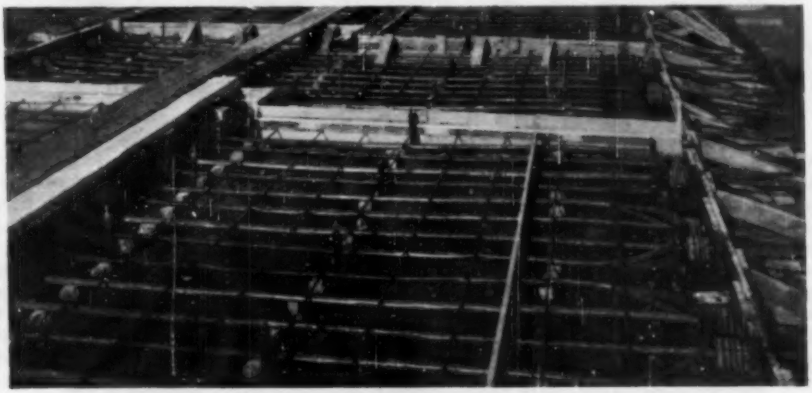


Fig. 5.—Arrangement of Cables in the Upper Slab.

The cantilevered footpaths were constructed last, the reinforcement having been cast in the beams and left protruding from the top flanges (the bars were bent into a vertical position when the beams were erected, as shown in *Fig.* 4).

The approaches comprise a culvert below ground which accommodates the conveyors. The roof of the culvert is a 9-in. prestressed in-situ slab which carries the railway.

Materials and Stresses.

The mixtures used were: Prestressed concrete, 1 : 1½ : 3; reinforced concrete, 1 : 2¼ : 3¾; topping on the top and bottom slabs, 1 : 3 cement and sand. Ordinary Portland cement was used, and the materials were proportioned by weight. The concrete was compacted by vibration. Crushing strengths were required of 4000 lb. per square inch at the time of stressing and 6000 lb. per square inch before the bridge was used. The maximum compressive stress due to a train is 1472 lb. per square inch, and there are no tensile stresses.

Preliminary Test.

A slab 5 ft. 4 in. wide by 9 in. thick was tested to destruction over a span of 16 ft. 3 in. The slab was prestressed by eight cables, each of twelve 0·2-in. wires, twelve days after casting, and was tested at an age of two months. The load was applied by hydraulic jacks through two steel beams placed on the slab symmetrically about its transverse centre-line and at 4 ft. 8½ in. centres to simulate the load due to the railway track.

The strains in the concrete were measured over a length of 10 in. on each side of the slab at mid-span at depths

below the top surface of ¾ in., 1¼ in., 6¾ in. and 7¼ in. The deflections were measured at mid-span on each side of the slab with dial-micrometer gauges, and similar gauges were fixed at the supports so that corrections could be made for movement at these points. For larger deflections during the later stages of loading, scales reading to 0·01 in. were used.

The slab was loaded in increments of 4 tons, at each of which the strains and deflections were measured. An upward deflection of ⅛ in. was caused by prestressing. The deflection under a load of 14 tons (equivalent to the working load) was about 7/16 in. The maximum load applied was 36·8 tons, when the deflection was about 2¼ in.; after removal of this load the deflection at the centre was ¼ in. A second application of this load resulted in a net central deflection of 3 in. and a deflection of ⅝ in. after removal of the load.

The work was under the direction of Mr. H. S. Barnett, L.R.I.B.A., Divisional Architect of the National Coal Board, and Mr. H. C. Griffiths, M.I.Struct.E., in collaboration with the Prestressed Concrete Co., Ltd. The construction of the abutments, the erection of the precast members, and the in-situ work were by Messrs. Fletcher & Co. (Contractors), Ltd. The precast beams were made by Messrs. Matthews & Mumby, Ltd., who carried out the prestressing; the test was made by this firm under the supervision of the Building Research Station.

Prestressed Precast Beams with Precast and In-situ Slabs.

THE Richard Gwyn Secondary School at Flint, North Wales, has composite precast and in-situ floor and roof slabs supported on precast secondary beams, and prestressed precast main beams. The main beams are supported on brick piers. Steel roof trusses were used over the assembly hall and gymnasium.

Generally the main beams span 26 ft. and are at 8 ft. 6 in. centres. The imposed load on the roof is 25 lb. per square foot and on the floors 120 lb. per square foot. The main beams are of rectangular cross section, 10 in. wide and 1 ft. 8 in. or 1 ft. 3 in. deep. The heaviest beam weighs 3½ tons and is 27 ft. 3 in. long. These beams are prestressed by 0·2-in. high-tensile wires; beams 1 ft. 8 in. deep contain 70 wires and beams 1 ft. 3 in. deep contain 56 wires. Because of a restriction in the overall depth of construction, pockets were formed in the upper faces of the main beams to receive secondary beams at about 4-ft. centres.

The secondary beams are 8 in. deep by 5 in. wide and are of precast reinforced concrete. To reduce the size of the pockets the ends of the secondary beams are rebated to form nibs, 4 in. deep and projecting 2 in., which fit in the pockets. The pockets were 1 in. wider than the beams to allow mortar to be packed in the joints. These beams weigh about 3½ cwt. each. The beams support precast reinforced concrete slabs 1¾ in. thick on which is a sand-cement topping 1¼ in. thick. The slabs are 2 ft. wide and vary in length from 2 ft. 6 in. to 5 ft. 3 in., most of them being 4 ft. long. The upper surfaces of the slabs were roughened to bond with the topping; the composite slab was designed so that the neutral plane is at the junction of the precast and in-situ parts so that the topping is always in compression.

Because of the possibility that the packing of the mortar between the nibs of the secondary beams and the sides of the pockets in the main beams would be unsatisfactory, the compressive strength of the main beams was calculated on the net area. One main beam was tested to failure and had a moment of resistance of 2,095,000 in.-lb. compared with a computed moment of resistance of 1,614,000 in.-lb. The deflection before failure was 2 in.

The architect is Mr. Patrick M. White and the consulting engineer Mr. John C. Maxwell-Cook, A.M.I.C.E. The contractors were Messrs. A. N. Coles & Co., Ltd. The prestressed precast beams were made by Pierhead, Ltd., and the precast beams and secondary beams and slabs by Ferroconcrete (Lancashire), Ltd.

Factory at Brighton.

This building (*Figs*. 1, 2 and 3) comprises a lower ground floor of 15,000 sq. ft., a factory floor at ground floor level of 42,000 sq. ft., and offices and canteen of 15,000 sq. ft. on the upper floor. The two-story part of the structure is of reinforced concrete frame and beam-and-slab construction. The floor of the factory area is of flat-slab construction, and this part, together with the canteen, is covered with a shell roof. The building is on chalk and the site slopes about 1 in 8. The two-story part is on the high ground adjacent to an existing road, and the first floor is nearly at road level. The lower ground floor is served by a road at the lower level which is connected to the upper road at each end of the building; this floor, which is used as a garage and for storage, is partly on virgin soil and partly on chalk filling and is bounded on three sides by reinforced concrete retaining walls.

The flat-slab floor over the garage and store has slabs 20 ft. by 18 ft. 9 in. between the columns with drop panels 3 in. deep by 8 ft. square. The floor was designed for a superimposed load of 336 lb. per square foot. The columns are 21½ in. diameter, and were built by placing concrete in precast pipes 1⅛ in. thick which served as permanent shuttering. This was economical and provides a very good finish to the columns. The circular column-heads were cast in timber shuttering.

The shell roof over the factory consists of twelve bays each 60 ft. long by 37 ft. 6 in. wide; the total width of the roof comprises two bays, that is 120 ft. The central tie and the tie adjacent to the two-story building are solid while the ties on the front of the building consist of six continuous arches 2 ft. 6 in. deep by 1 ft. 3 in. wide spanning 37 ft. 6 in. At two places in the ends of the shells there are openings for helical stairs from the factory to the office on the first floor.

Fig. 1.

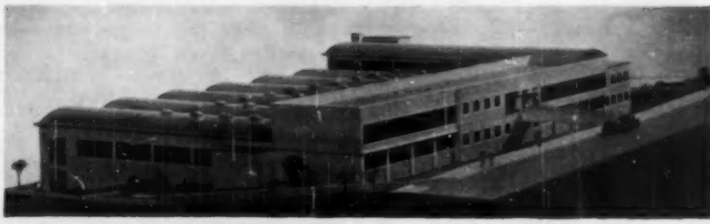


Fig. 2.

The shells are 3 in. thick at the centre, and this is increased slightly near the valley and edge-beams. Circular domed lights are provided in the shells adjacent to the two-story structure. Lighting is by fluorescent tubes in troughs attached to the vaults.

Two continuous shells 80 ft. long and 40 ft. wide are provided over the canteen and kitchen respectively; these sizes were used to avoid a tie in the canteen. The roofs are covered with 1½ in. of

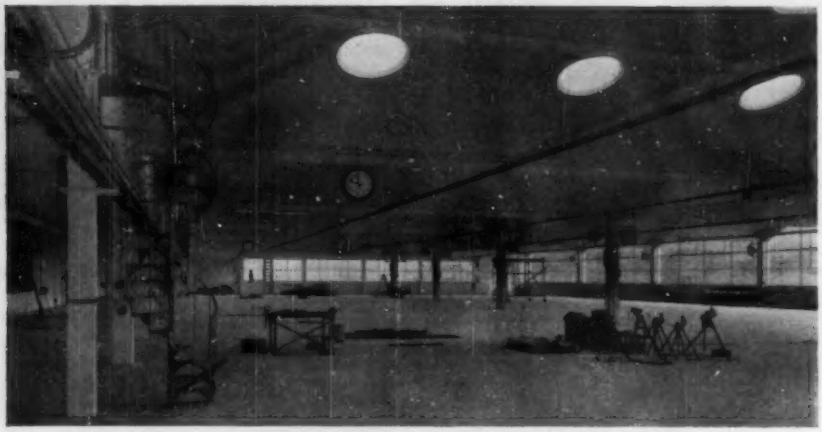


Fig. 3.

foamed-slag concrete to provide insulation, and this is covered with two layers of bituminous felt.

The two-story part extends the full length of the building (about 263 ft.) and is about 40 ft. wide. A reinforced concrete bridge connects the office on the upper floor with the main road.

The work was started in February 1952 and completed in October 1953, the total cost being about £122,000. The architectural work was by the Engineer and Surveyor's Department of the Brighton Corporation, under the supervision of Mr. D. J. Howe, M.I.C.E., Borough Engineer and Surveyor; Mr. P. Billington, A.R.I.B.A., was chief architect, and Mr. R. F. West, A.R.I.B.A., assistant architect in charge of the work. The reinforced concrete work and the "Archspan" roof were designed by the Liversedge Reinforced Concrete Engineering Co., Ltd. The general contractors were Messrs. Rice & Son, Ltd.

Barley Silo in Yorkshire.

THE barley silo at Knapton, near Malton, Yorkshire, for Associated British Maltsters, Ltd., has a maximum height of 125 ft., and comprises bins 65 ft. high, with a capacity of about 30,000 quarters, a nine-story dryer house, and an intake pit with a capacity of 50 quarters. The construction is of reinforced concrete throughout. The silo has 42 main bins, eight bins for storing "green" barley, and four small loading-out bins. The column loads were carried to "Holmpress" piles by means of deep stepped foundations and a slab covering the whole area of the superstructure. The external finish is a silver grey shade of cement paint, which was also largely used internally.

The architects are Messrs. Gelder & Kitchen, and the contractors were the Mitchell Construction Co., Ltd. The reinforced concrete details were prepared by the Indented Bar & Concrete Engineering Co., Ltd.

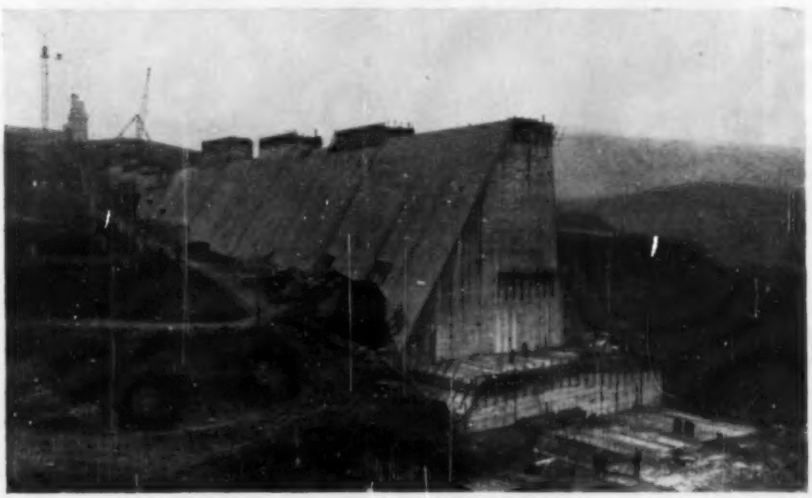
Reservoir in Scotland.

THE Upper Glendevon reservoir in Fifeshire is being created by a plain concrete dam 1250 ft. long and 130 ft. high enclosing the valley of the river Devon immediately upstream of an existing reservoir. The dam will contain about 180,000 cu. yd. of concrete. The aggregate from 2½ in. to No. 100 sieve is produced on the site, and to this is added river Tay sand from Perth.

The concrete is mixed in a 2-cu. yd. batching plant. Cement is received in bags and is emptied into a silo of 210 tons capacity incorporated in the plant. The materials produce a very harsh mixture, and an air-entraining agent is added to improve the workability of the concrete. The concrete is placed by a radial cableway carrying 4 cu. yd. bottom-dump buckets which are filled from the mixer discharge-hopper, by means of a swivelling chute, without being detached from the cableway. The whole of the plant is electrically driven.

Steel Shuttering.

Construction of the dam is proceeding in blocks 50 ft. long, and all faces of these monoliths are shuttered with steel panels and soldiers of heavy-section steel channel. The shuttering is on the cantilever principle, using coarse-threaded tapered screws of large diameter built into the concrete as anchors. Mobile cranes of 2 tons capacity and hand-operated hoists are used for lifting the shutters, the cranes being moved from one monolith to another by the cableway. As the



Dam during Construction.

shutters are lifted the lower anchor-screws are recovered for re-use and the holes left by their withdrawal plugged with mortar.

The crest of the spillway and a bridge over the spillway will be constructed in precast concrete made on the site. So far about half of the concrete has been placed and the dam is due for completion towards the end of the year.

Messrs. Leslie & Reid are the consulting engineers, and Messrs. Holland & Hannen and Cubitts (Scotland), Ltd., are the contractors.

A Curved Staircase.

THE staircase shown in *Fig.* 1 is roughly elliptical in plan and rises 12 ft. 6 in. from the ground floor to the first floor of a building at Gosforth, Newcastle-on-Tyne.

The distance between the walls, and the clear span of the curved landing, are 23 ft. 3 in. The width of the staircase is 4 ft. 6 in., which is also the least width of the landing at midspan. The waist of the staircase and the thickness of the landing slab are 9 in. A granolithic finish to the steps and landing was laid after the concrete was placed but is not included in the structural depth. The soffit of the landing and staircase is plastered. The main reinforcement is $\frac{5}{8}$-in. twisted square high-tensile steel bars at 6-in. centres, which were supplied bent. The shuttering was timber.

The curved window behind the staircase has 12-in. by 3-in. reinforced concrete mullions supporting a curved beam and a 4-in. slab over the bay.

The architect is Mr. Clarance Solomon, A.R.I.B.A., A.R.I.C.S., and the structural design was by the Square Grip Reinforcement Co. (Gateshead), Ltd., who also supplied the reinforcement. The contractors were Messrs. Cussins (Contrs.), Ltd., at whose offices the staircase was built.

Fig. 1.

Lining the Haslingden and Walmersley Tunnels.

High Speed obtained by Use of Concreting Train.

By O. DAWSON, B.Sc., A.M.I.C.E., and A. S. BERTLIN, A.M.I.C.E.

Introduction.

THE task of lining with in-situ concrete a tunnel eleven miles long afforded ample opportunity for mechanisation in placing the concrete, and full use of this opportunity has been made on the Haslingden and Walmersley tunnel sections of the Haweswater Aqueduct, where a concrete-mixing and placing train is at work. *Fig.* 1 is a longitudinal section of the two tunnels, which total eleven miles in length. In the main, they are driven through nearly horizontal strata of shales and sandstones, although some lengths pass through old coal workings,

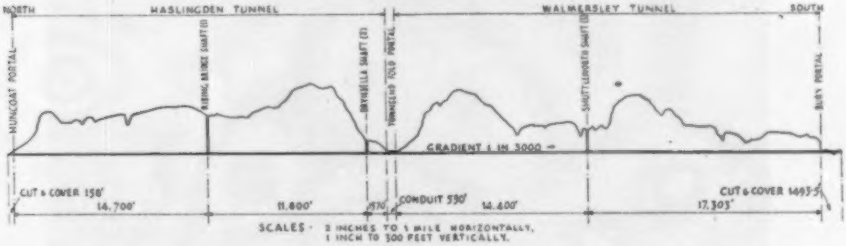


Fig. 1.—Section.

mostly in a collapsed state. The cross section of the tunnel is horseshoe with an equivalent diameter of about 11 ft. for the ground work. Steel arch-ribs and laggings are used to support the ground except in relatively short lengths through sandstone where supports are not necessary. In exceptionally poor ground the tunnels are lined with reinforced concrete segments of 10 ft. 6 in. internal diameter as driving proceeds. Many schemes were considered for placing some 150,000 cu. yd. of concrete in 60,000 ft. of tunnel lining, and it was finally decided to use sufficient length of shutter and concreting equipment of sufficient capacity at one working point to allow concrete to be continuously placed throughout 24 hours a day for a week at a time.

The Concrete Plant.

It was thought that there were advantages in mixing the concrete near the shutters, and dry-batching outside the tunnels. By mixing near the shutters the concrete-placing equipment is supplied with concrete that has not segregated due to handling, and in this case the distances that the concrete would have to travel underground if it were mixed outside the tunnels were such that a delay of an hour or more might occur between mixing and placing. The plant used for batching was too large to go inside the tunnel and it was therefore built in the open, at the middle of the work, at Townsend Fold. It was intended to start the lining-train at points farthest from the middle and work towards the

middle, but this arrangement had to be modified in one direction due to the length of one of the tunnel drives.

The track laid in the tunnel for removal of the spoil was 2 ft. gauge, and as side-tipping wagons of 25 cu. ft. capacity were available from the spoil haulage it was decided to use ½ cu. yd. batches of concrete for the lining. The volume of unmixed materials for this size of batch is 20 cu. ft., which can be carried in these wagons. Apart from the size of the wagons it would have been very difficult to use a 1 cu. yd. mixer in the tunnel with a suitable arrangement for delivering the dry materials.

The problem of obtaining up to 30 cu. yd. of concrete an hour from a ½ cu. yd. mixer was solved by employing a twin-drum paving mixer. This type of mixer is well known in the 1 cu. yd. size mounted on track and used for concreting

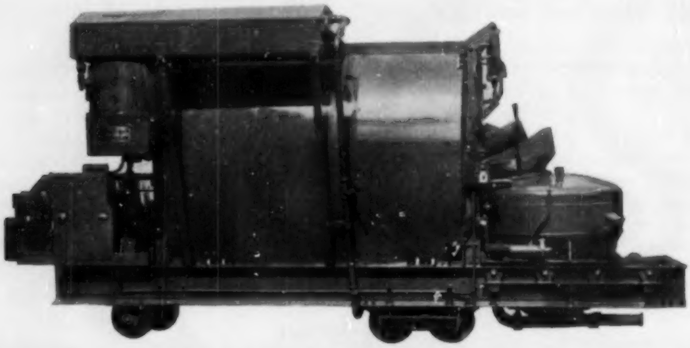


Fig. 2.—The Concrete Mixer and Placer.

roads and runways, but it is believed that this is the first ½ cu. yd. machine made in this country. The mixer is fed by a 30-in. inclined belt-conveyor on to which wagon-loads of dry batched material are tipped one at a time. *Fig. 2* shows the mixer without the conveyor. The drum has two compartments with a chute for transferring the mixture from one compartment to the other. Dry material is delivered into the first compartment by gravity from the conveyor and the mixed concrete is discharged from the second compartment by means of a discharge chute operated by compressed air. The sequence of mixing is controlled by an automatic electric timing mechanism.

As soon as the mixed concrete has been discharged from the drum, the operator presses a button which starts the mixing cycle. A wagon of dry material is tipped on to the conveyor, and almost simultaneously the chute transfers the mixture from the rear to the leading compartment, so that the rear compartment is emptied before the new batch reaches the top of the conveyor. As the dry batch enters the rear compartment the water-valve opens, allowing the required quantity of water to enter the drum. The operator cannot discharge the mixed concrete from the leading compartment until the timed cycle has been completed. The leading drum of the mixer discharges into a ½ cu. yd. pneumatic placer which is under the control of the mixer driver, as shown in

Fig. 3. From the placer the concrete is delivered directly into the shutters through a pipe-line of 6 in. diameter. In order to equalise the surges in the compressed air used by the placer, a large air-receiver is carried at the end of the concreting train nearest the shutter.

The concreting train (*Fig.* 4) consists of the air-receiver wagon, the mixer-placer wagon, the belt-conveyor for supplying the mixer, and finally the winch wagon. All these are mounted on wheels and, as the concrete lining advances, the train is moved along the tunnel by means of the winch wagon. There is

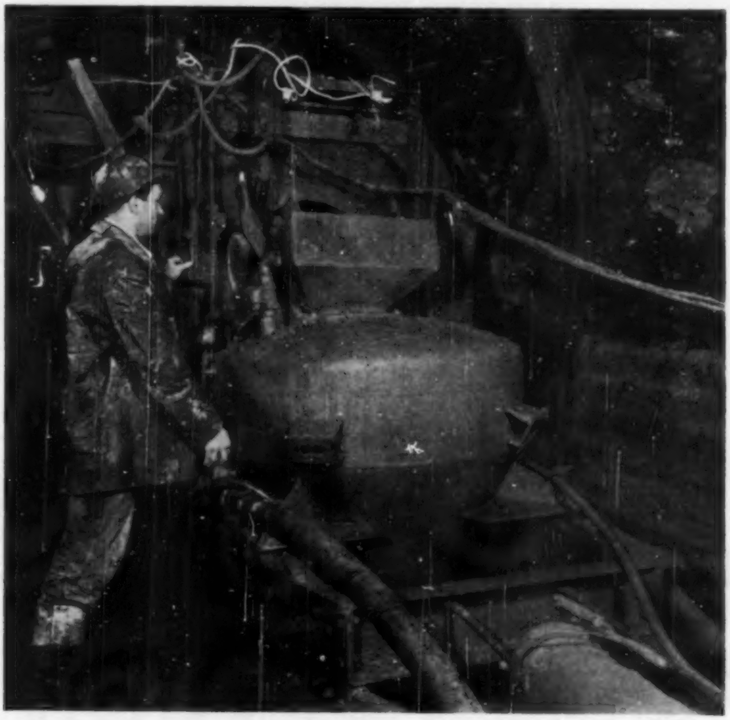
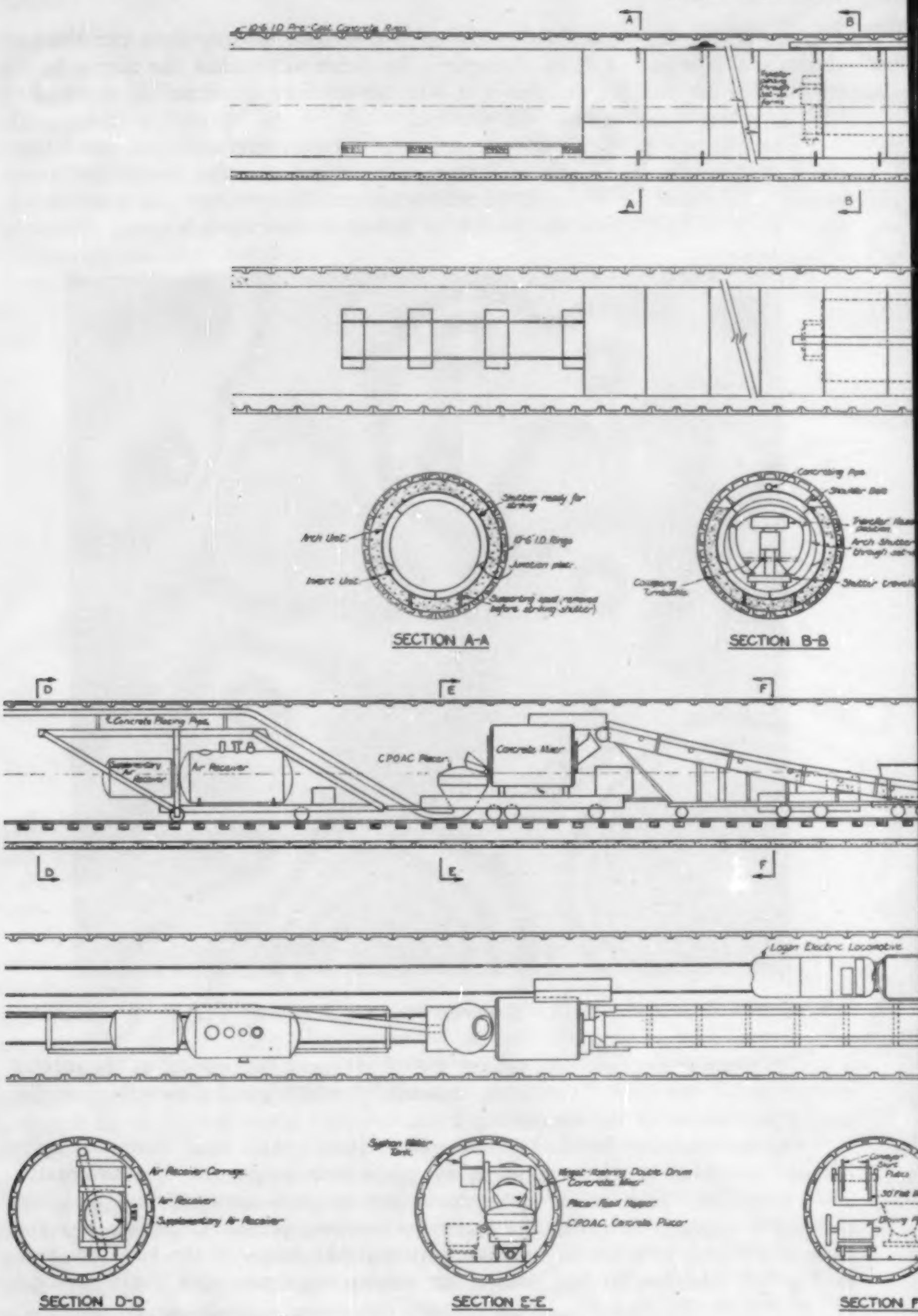


Fig. 3.—Concrete Placing Machine.

a double track throughout the tunnel, and shunting of the wagons at the mixing end is carried out on a " California crossing " * which can be moved along the tracks just ahead of the concreting train.

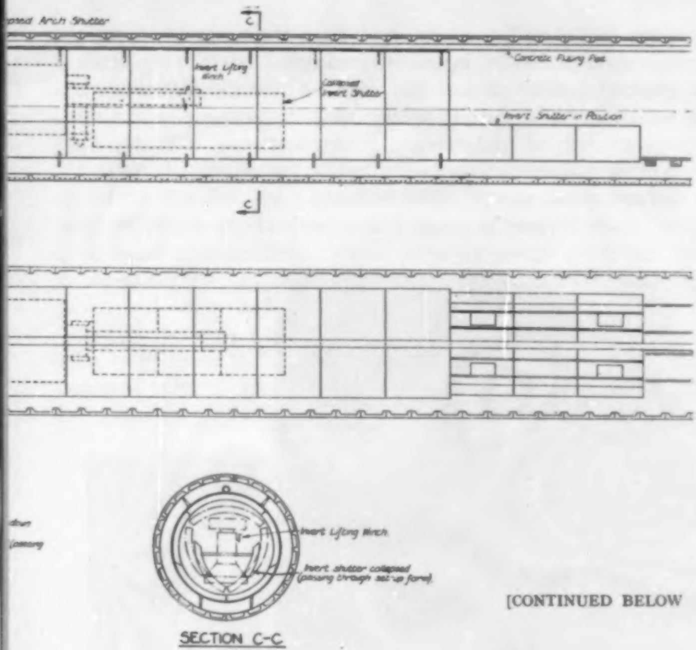
The materials are batched in the open (*Fig.* 5). As a peak output of sixty batches per hour is required, as many operations as possible are automatic. The coarse aggregate, sand, and cement are weighed automatically and discharged in sequence into a wagon under the batching plant. Cement is received loose and stored in a bin of 200 tons capacity (the larger of the two bins seen in *Fig.* 5) ; the smaller bin is used for storing aggregate over the automatic

* A California crossing was described in this journal for November, 1952.

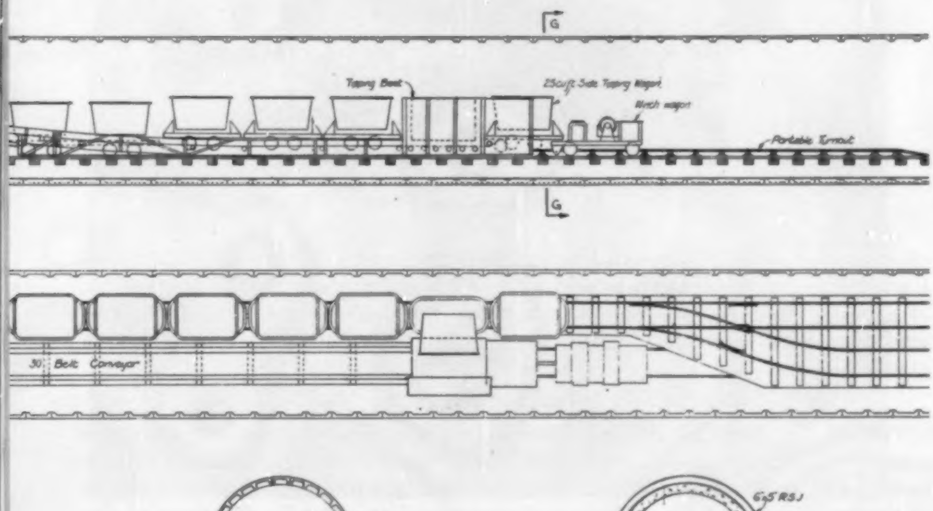


CONTINUED FROM ABOVE)

Fig. 4.—Plan an



[CONTINUED BELOW



nd ection of Tunnel.

weighers. Coarse aggregate and sand are transferred from the main stock-piles to the aggregate bin by a conveyor which is fed by two belt-feeders from small surge-hoppers charged from the stock-piles. Two 10-tons derricks fitted with grabs are also used in reclaiming the aggregate and sand from the stock-piles, which contain about 5000 cu. yd. of materials.

All the batching and mixing operations are recorded by an automatic counter at the batching plant and by an ammeter. The ammeter is fitted in the electrical circuit of the motor which drives the mixer; it records the speed at which

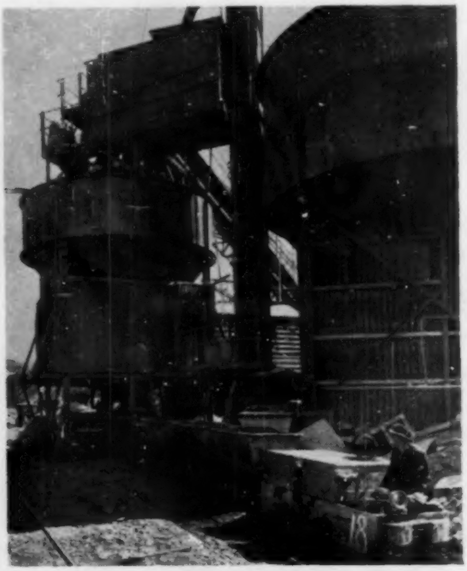


Fig. 5.—The Batching Plant.

each train of wagons is unloaded and the time intervals between each train. Each train of nine wagons is hauled by a 12-h.p. battery electric locomotive and, as a journey from the batching plant to the mixer and back may be a distance of ten miles, there is an arrangement for changing the batteries at the batching plant.

The Shutter.

As no stunt-end shutters are employed, a sufficient length of shutter is required to support the concrete, which is placed continuously and allowed to find its natural slope at each end of the circular shutter. An additional length of shutter is required for striking and setting and to allow for the slope of the concrete at the ends. The shutter is 240 ft. long, divided into sections 15 ft. long.

As the inside of the lining is only 8 ft. 6 in. diameter it was decided to depart from the usual method of placing the invert separately from the sides and top, and to place the whole circle in one operation. The 15-ft. lengths of shutter

are divided into invert and top sections. The invert sections are hinged at the centre and the top sections are hinged at the two shoulder points so that the complete circle can be collapsed on to a travelling carriage which takes a 15-ft. length from one end of the shutter to the other. The carriage travels on rails built into the invert shutter.

The shutter is supported on steel "spuds" which can be screwed up or down for levelling purposes. Similar spuds are provided at the shoulders to stop any tendency to float, but it is found that these are seldom necessary when concreting continuously. Both these types of spuds are seen in *Fig.* 6, which is an end view of the shutter, while *Fig.* 7 shows a folded top section being taken out on to a levelled invert section.

Fig. 4 shows the arrangement of the shutter and the concrete train. It is seen that there is limited space only between the end of the shutter and the concrete train to allow for removal of the track and for clearing the invert ready for concreting. Because of this limited space (and time) the tunnel is first cleaned

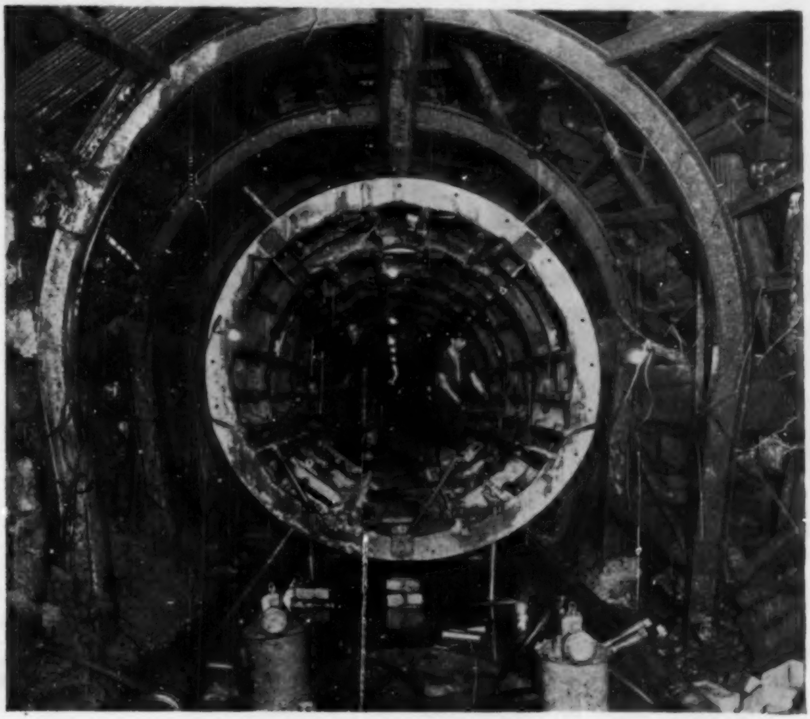


Fig. 6.—Shutter in Position.

out and a rough sub-invert of concrete laid to the grade of the finished lining. The steel levelling spuds stand on this sub-invert and are withdrawn after the lining is placed. The lining has frequently been placed at a speed of more than 1200 ft. per week, and as much as 1400 ft. per week have been attained on

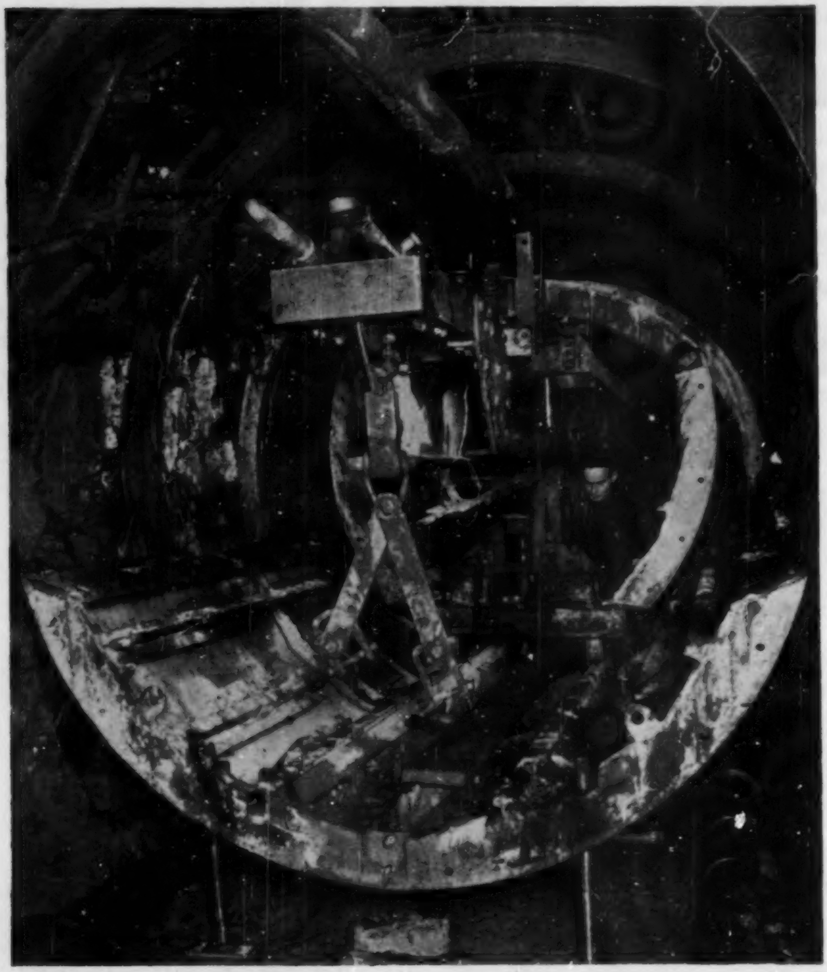


Fig. 7.—Top of Shutter Collapsed for Removal.

occasions. In one working period of four weeks, more than a mile of lining was completed.

The Haweswater Aqueduct is being built to the requirements of the Manchester Corporation Waterworks Department, of which Mr. Alan Atkinson, M.Eng., M.I.C.E., M.I.W.E., is Engineer and Manager. The contractors for the Haslingden and Walmersley tunnel are Edmund Nuttall, Sons & Co. (London), Ltd. The shutters were supplied by Blaw Knox, Ltd., who also supplied the batching plant and conveyor for feeding the mixer. The twin-drum mixer was supplied by Winget, Ltd., and the pneumatic placer by the Compagnie Parisienne d'Outillage à Air Comprimé of Paris.

Prestressed Railway Bridge in Staffordshire.

THIS bridge, which was constructed at Bilston during the early part of last year, spans over a canal and connects the works of Messrs. Stewarts & Lloyds, Ltd., and Tarmac, Ltd. It is to be used almost entirely by trains carrying slag from blast-furnaces. Temporary staging (*Fig.* 1) was provided so that the canal traffic was not interrupted, and a clear way of 20 ft. was left in the middle of the canal.

shearing stresses were not high at the junction of the webs and the slab, and this method of placing the concrete enabled joints across the deck at midspan to be avoided. A small amount of mild steel reinforcement was provided in the top flanges, in the vertical stiffeners, and in the ends of the beams.

To prevent the cables moving out of position whilst the concrete was placed

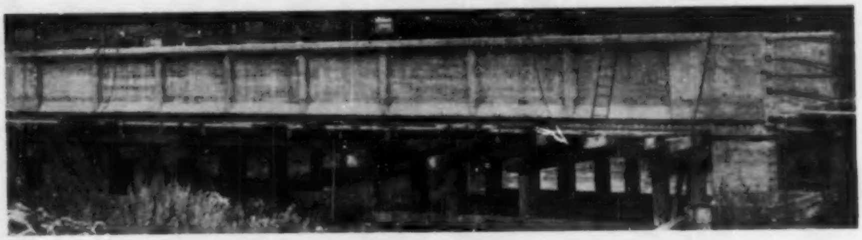


Fig. 1.—Bridge During Construction.

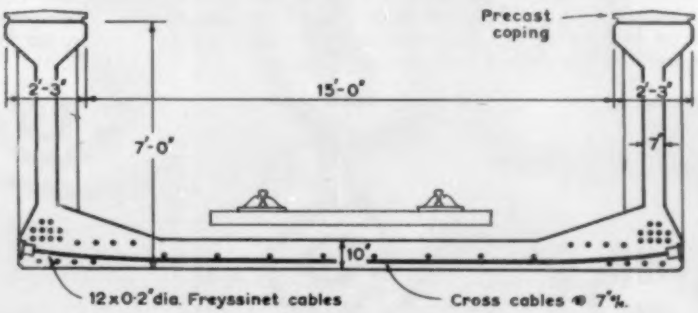


Fig. 2.—Cross Section.

Bridge Deck.

The span is 73 ft. 6 in. between the abutments and 77 ft. 6 in. to the centres of the bearings. A single line of ballasted track is carried on a slab 10 in. thick spanning between two beams each 7 ft. deep and 15 ft. apart (*Fig.* 2); this permitted the maximum clearance over the canal. The slab and the beams were prestressed by cables in plastic sheaths. The whole of the slab was cast at one time to the level of the junction of the webs of the beams and the slab. The webs and upper flanges of the beams were cast afterwards. It was considered that the

and vibrated, mild steel supports were provided (*Fig.* 3). These " hat racks " as they were named provided an easy and accurate method of fixing the cables in position. To prevent any mild steel being exposed on the surface the ends of the small cross-bars in the web of a beam were capped with domed brass cups which, although placed directly against the shutters on each side, are not visible. *Fig.* 4 shows the bridge during construction with the cable supports in place.

The best proportions for the concrete were determined during the casting of the abutments. The required cube-strength

was 6000 lb. per square inch before tensioning the cables or at 28 days. Tensioning was carried out after the last cubes made at the time of concreting the upper sections of the beams had reached this strength.

A camber of 2 in. was given to the main span. The calculated upward deflection of the bridge after prestressing was very small. After considering various possibilities, simple sliding plates, sealed in grease, were used for the bearings. Consequently care had to be taken to ensure that the full longitudinal contraction due to prestressing took place freely. "Pop" marks were made on the upper and lower bearing-plates and a plumb-line was marked on the wall at each abutment. During the tensioning of the cables there was no deviation from the vertical, and the total lateral movement at the bearing was about ⅛ in., which was very nearly the calculated value.

Foundations.

The abutments are of the open-box type, with the open side facing the canal, founded on precast reinforced concrete piles. Careful siting of the piles was

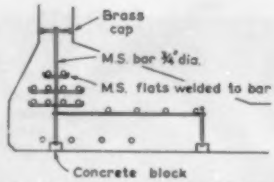


Fig. 3.—Supports for Cables.

necessary to avoid the clay puddle to the canal and at the same time provide clearance for the towpath. The use of an open box was considered desirable to reduce the surcharge due to the railway embankment by keeping it as far back as possible from the bank. As a further precaution a beam was used to span from the back of the abutments on to a plain concrete foundation at the top of the railway embankment.

The bridge was constructed for Messrs. Stewarts & Lloyds, Ltd., at a cost of about £8000. The contractors for the piling, reinforced concrete, and prestressed concrete were Tarmac, Ltd., and the prestressing cables and equipment were supplied by P.S.C. Equipment, Ltd. The design was prepared by Mr. Walter C. Andrews, O.B.E., M.I.C.E., M.I.Struct.E.

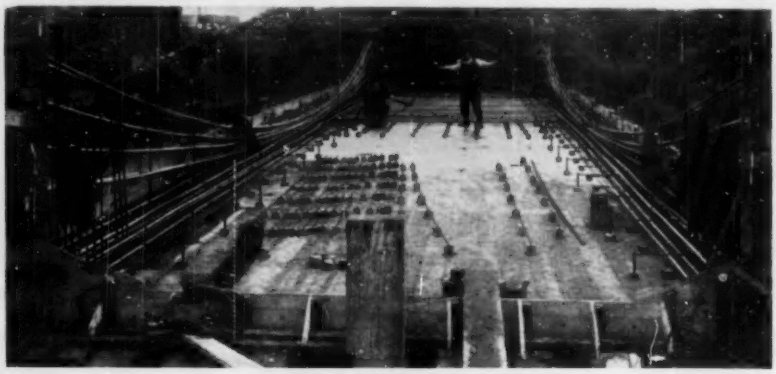


Fig. 4.—Placing the Cables.

"BLAWFORM"

TUNNEL SHUTTERING

is being used for the construction of

HASLINGDEN and WALMERSLEY TUNNELS of the HAWESWATER AQUEDUCT

for the Manchester Corporation Waterworks Department

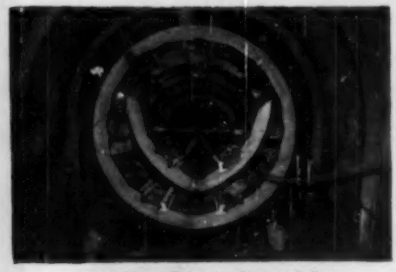
Engineer and Manager:

Alan Atkinson, M. Eng., M.I.C.E., M.I.W.E.

Main Contractors:

Edmund Nuttall Sons & Co. (London) Ltd.

Looking forward from finished lining to progress and showing "Blawform" shuttering in position.



Invert form collapsed and suspended on boom arm of traveller.

"Blawform" tunnel shuttering is sturdily built, suitable for all methods of concrete placing, permitting full-round construction. The telescopic sections are easily handled and are speedily struck and reset, thus reducing cost per yard super.

Invert form lowered into position and crown form being advanced on traveller for setting to make the full circle.

BLAW KNOX LIMITED

90/94 BROMPTON ROAD, LONDON, S.W.3

Telephone: KENsington 5151

Telegrams: BLAWNOX, SOUTHKENS, LONDON

Cables: BLAWNOX, LONDON

BK 83

Prestressed Concrete Roof Beams at Victoria Station, Sheffield.

SEVENTEEN partly-prestressed concrete roof beams of 87-ft. 6-in. span have been erected to support a suspended steel roof over two platforms at Victoria Station, Sheffield (*Fig.* 1). The beams were made at a locomotive shed about three miles from the site, so that they could be taken to the site by rail. The shuttering was designed by the contractor, and two complete shutters were made at the contractor's yard and assembled at the locomotive sheds. A feature of the shuttering was the method of keeping in position the rubber cores through which the stressing cables were threaded. To facilitate easy withdrawal of the cores they had to be supported so as to remain straight while the concrete was placed, and the device shown in *Fig.* 2, made of ¼-in. diameter reinforcement bars wired to through-bolts, was successful. As the specification did not allow temporary shuttering bolts to project to the face of the beams, a shallow groove was cut in them 1½ in. from the face of the finished concrete, so that a twist of the bolt with pliers broke the bolt at the groove so that the projecting part could be withdrawn leaving a small hole to be filled with grout.

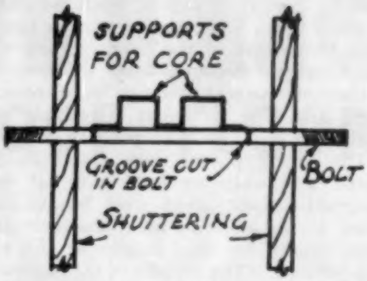


Fig. 2.

The concrete was a 1 : 3½ mixture which was consolidated with mechanical vibrators. Owing to the unusual length and depth of the beams, the concrete was placed from one end, the bottom flange being filled first, and then the remainder of the beam with the end of the concrete at an angle of about 45 deg.

Each beam (*Fig.* 3) is prestressed by two cables of sixteen 0·276-in. diameter hard drawn steel wires, which were tensioned by hydraulic jacks. In addition, four pairs of untensioned wires were placed in the tensile zone and two pairs in the compressive zone. The effective force applied to each tensioned wire, after allowing for frictional loss at the jack, was 7740 lb., corresponding to a stress of 130,000 lb. per square inch. After the cores had been withdrawn the ducts were filled by pressure grouting. It was not possible to give a definite time for removal of the shutters because of the risk of frost, but the side shutters were generally stripped after twenty-four hours.

During the tensioning of the wires the

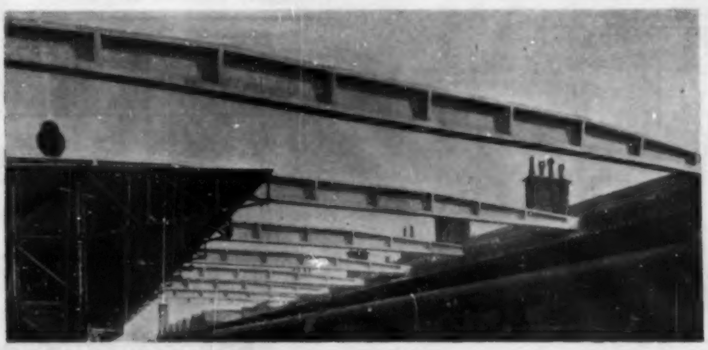


Fig. 1.

upward deflection at the middle of the beam was nearly 1 in.; an upward deflection of 2 in. was permitted by the engineer. Some of the beams were tested. Six steel ingots, each weighing about 2 tons, were placed at two places near the centre of the beam, which was supported at the ends only. The stress in the concrete was then 650 lb. per square inch, and was sufficient to enable the beams to be lifted into position.

The lifting points were about 80 ft. apart, and a lifting bale (*Fig.* 4) was designed consisting of steel beams stiffened at the sides by steel channels and cross braced by steel angles at the top and bottom. The middle of the bale was filled with timbers 12 in. square bolted through the webs of each side joist, with space left for the hook of the crane to pass into the centre of the bale for lifting. From each end of the bale a wire-rope and chain sling was attached to the lifting cradles under the beam. As each beam was lifted on to trucks, marks were painted on it to indicate its position in the roof, and other marks were painted on them, at a distance from one end of the required setting, to facilitate their alignment; the latter marks corresponded to a line set out between the tracks at the station, to which a theodolite was set. The beams were erected during two Sundays between the hours of 6 a.m. and 4 p.m. On the first day, nine beams were erected at the east of the platform, using a 36-tons railway breakdown crane, and (by theodolite) each beam was placed within ¼ in. of its correct position. This was important, as it would have been

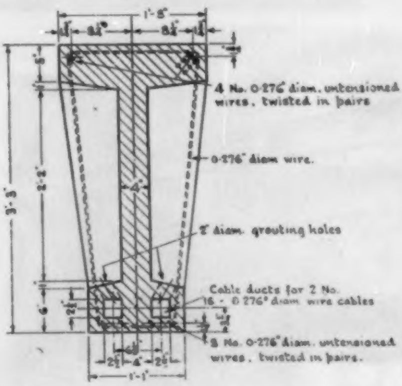


Fig. 3.—Cross Section of Beams.

Fig. 4.

impossible to move the beams longitudinally after they were placed because there was no solid face for a jack to bear against; the beams could, however, be jacked short distances laterally to obtain true centres between the beams. During another Sunday the remaining eight beams were erected in a similar manner.

After erection of the beams the general building work and station alterations were carried out by Messrs. Wellerman Bros., Ltd., who were the general contractors for the work and who made the beams, in readiness for the steelwork contractors, Messrs. S. Butler & Co., Ltd., to erect the suspended steel-framed and glazed roof. The suspension bars are of stainless steel. The work was carried out for British Railways, under the direction of Mr. J. I. Campbell, M.I.C.E., Chief Engineer, Eastern Region.

Maltings Structure in Lincolnshire.

THIS maltings (*Fig.* 1), recently completed at Louth, Lincolnshire, for Messrs. Gilstrap, Earp & Co., Ltd., is planned for completely mechanised handling of barley and malt, and is claimed to be the first fully-mechanised malting unit in this country; its conception is based upon research in the United States of America.

Storage is provided for dried barley and malt in 96 bins each 8 ft. by 8 ft. by 85 ft. high. Barley as harvested is delivered to a large underground chamber, from which an elevator 140 ft. high takes it to drying and cleaning plant in the eight-story building above.

The maltings contains four elevated hoppered steeping-cisterns, 15 ft. diameter by 20 ft. high, from which the barley passes to an eight-compartment germinating room (*Fig.* 2) supplied under pressure with conditioned air from a separate refrigeration plant house. Following germination the green malt is kilned, two

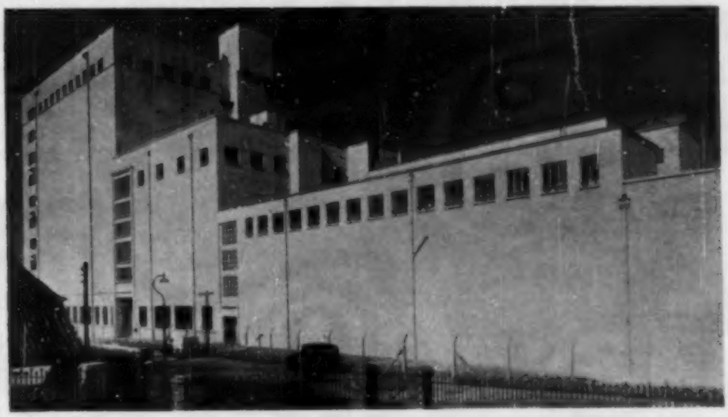


Fig. 1.

Fig. 2.—Germinating Department.

kilns being provided, and is finally graded and dressed during its passage through a five-story building for despatch to the silos, as required.

The foundations of the silo and malting buildings are in-situ concrete piles with slab or continuous-strip pile caps. The construction is of reinforced concrete throughout with beam and slab floors, with the exception of the germinating house which has a flat-slab floor. The external finish is cement paint.

The architects are Messrs. Gelder & Kitchen. The contractors were The Mitchell Construction Co., Ltd. The reinforced concrete design and details were prepared by the Indented Bar & Concrete Engineering Co., Ltd.

Generating Station at Hackney, London.

A GENERATING STATION for British Electricity Authority is being constructed on the site of an existing station on the Hackney Cut Navigation, a cutting from the river Lea. The first part of this project, to house three 30,000 kV. sets, three boilers, and associated plant, commenced at the beginning of 1951 and the plant is now being installed.

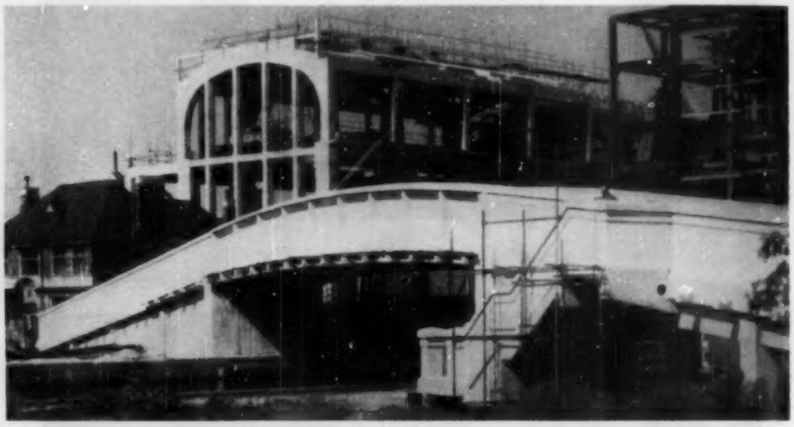


Fig. 1.—Prestressed Bridge. Turbine House in Background.

Prestressed Bridge.

Part of Hackney Marshes has been procured to form a new coal stockyard. To reach this a footbridge across the Cut has been replaced by a new bridge (*Fig.* 1); the approaches are of reinforced concrete, the span over the canal is prestressed, and the parapets are precast. The required headroom left a depth of only 3 ft. 8 in. for the canal span of 78 ft. 6 in., and a prestressed slab with a depth of 2 ft. 8 in. was adopted. Fourteen prestressed precast members, 2 ft. 8 in. deep at midspan and 1 ft. 8 in. deep at the supports, were used to form the slab. The members are 11 in. wide and spaced to form a deck 14 ft. wide; the 1-in. gaps between the members were filled with cement mortar.

The members were delivered in four sections 20 ft. long and containing a small amount of mild steel reinforcement. These sections were placed together end to end on a prepared bed, with a gap 6 in. wide between them. The gaps were filled with dry concrete and prestressing cables were threaded through ducts previously formed in the members. The cables were then tensioned and the members hoisted into position. The deck was finally prestressed transversely by cables at 5-ft. centres. The road surface over the prestressed span consists of 4 in. of tarmacadam. The bridge is designed for

the Ministry of Transport Standard Loading.

The Generating Station.

The foundations of the generating station are on piles bearing on a layer of black pebbles, cemented in places, at a depth of about 25 ft. Previous to the driving of the piles the site was enclosed with steel sheet-piles and the foundations of part of the existing station removed.

Reinforced concrete culverts for the cooling water for the condensers pass through the foundations. One of these culverts rests directly on the black pebbles, and in places the partly-cemented layer had to be excavated. This was done by first driving steel sheet-piling, in the form of a box, as far as was possible into the hard layer. The subsoil was then excavated and the hard layer removed, thus allowing a second line of sheet piles to be driven inside the line of those driven first. It was then possible to excavate to the required depth.

The boiler-house is a steel frame with reinforced concrete floors and roof. The turbine-house, switch-house and control-room, precipitator-house, chimney-stool, coal-tower, and administrative building are of reinforced concrete. The roof of the turbine-house is a curved slab spanning on to arch ribs and was constructed by a travelling shutter supported by the crane-rail. The roof contains glass lights and has a continuous central vent.

The switch-house, with three floors, is adjacent to the turbine-house; on one side it is supported by the columns of the turbine-house to which it is connected by cable-tunnels at the level of the operating floor.

The chimney-stool is an integral part of the frame and accommodates plant at various levels. The chimney, 300 ft. high, will be constructed in reinforced concrete made with a coloured cement. An acid-resisting brick lining will be separated from the concrete by an air space.

Coal will be delivered by barge and unloaded by cranes on tracks supported on reinforced concrete beams which are part of a new wharf which has been constructed on the bank of the Cut.

An intake for the culverts has been partly constructed about 2250 ft. to the north of the station. From this intake a culvert has been constructed in open cut, with the aid of sheet-steel piling, to a tunnel which is being constructed under Lea Bridge Road and Lea Bridge Place. In order to construct this tunnel, of cast-iron segments with concrete backing, the ground above it has been chemically consolidated to ensure that services under the road and the traffic will not be disturbed during operations. From the other end of the tunnel a culvert with a screen-chamber is being built to connect with the cold-water culvert in the station foundations. A discharge chamber is to be constructed at the south-east corner of the site to join with the hot-water culvert in the foundation. The cold-water culvert will, however, be extended under this discharge chamber and pass under the Cut by way of surge and screen chambers to the cooling tower. Another intake chamber will be constructed on the east bank of the Cut and connected by cast-iron pipes to the cooling tower. An emergency discharge chamber will then be constructed at the end of these pipes, just past the cooling tower, on the bank of the river Lea.

The consulting engineers are Messrs. L. G. Mouchel & Partners, Ltd. The contractors are: demolition, Messrs. Wackett Bros.; foundations, prestressed bridge, wall of coal stock-yard, wharf, reinforced concrete frames and walls and turbo-generator building, Messrs. J. L. Kier & Co., Ltd.; intake works, including the tunnel under Lea Bridge Road, Messrs. John Morgan (London), Ltd.

Residential Flats at Edinburgh.

THE flats for the City of Edinburgh shown during construction in *Fig.* 1 have now been completed. They comprise six buildings in the form of a crescent, and two of the buildings are curved in plan to an inside radius of 150 ft. The buildings are eight stories high and 30 ft. wide; five are 88 ft. long and one is 58 ft. long. The top floors of four of the buildings 88 ft. long form a nursery school and playground. There are 88 flats of which 74 have four apartments. The story-heights are 11 ft. in the classrooms, 9 ft. 10 in. on the ground floor and 9 ft. 4 in. elsewhere. Under one of the buildings is a heating chamber and fuel store measuring 60 ft. by 45 ft. by 12 ft. deep.

The construction is reinforced concrete columns, beams, floors, staircases, and balconies, with external walls 10 in. thick comprising an outer leaf of 2-in. precast concrete slabs (with continuous vertical joints), a 3½-in. cavity, and an inner leaf of 4½-in. bricks. The slabs are carried on nibs projecting 6 in. from the external beams at each floor level. The end walls, the walls dividing the buildings, and walls to the lift-wells and staircases are of brick. All partitions are of lightweight concrete blocks 3 in. thick. Expansion joints are provided between all the buildings, except between that 58 ft. long and the adjoining building. Twin columns and beams are used at the joints, with 4½-in. brick walls on each beam and separated by a 3-in. cavity. The structures are designed in accordance with B.S. Codes of Practice No. 3 (Chapter V) and No. 114 (1948).

The site is nearly level. The ground consists of 11 ft. of loose gravel and 2 ft. of soft silt overlying boulder clay. The foundations are piled and 315 18-in. diameter in-situ piles in lengths from 17 ft. to 22 ft. were formed in the boulder clay in groups of two, three, or four. The foundations of the heating chamber are integral with the floor and rest on plain concrete piers taken at least 6 ft. into the clay. The water-table is about 5 ft. below ground level, and the basement is made watertight with bituminous sheeting between the column footings and the piers.

The ground floors (except over the heating chamber) are inverted trough-shaped precast beams 5 ft. to 8 ft. 6 in. long by 1 ft. 4 in. wide by 7 in. deep. These were cast on the site. The moulds for the channels were 10-gauge pressed steel troughs 11 in. to 12 in. wide by 5 in. deep, with 1-in. lips along each edge. The troughs were 3 ft. and 6 ft. long and overlapped to give the lengths of beams desired. The floor-beams are supported on rectangular beams spanning between the pile caps and are covered by a 1-in. sand-cement topping, or by granolithic. Other floors are 7 in. and 9 in. deep of in-situ trough construction. The ribs were formed by the steel troughs used as moulds for the ground-floor beams. In the straight blocks the ribs are 3½ in. wide at the bottom and in the curved blocks 5 in. wide. The reinforcement was bent on the site. Hardwood wedge-shaped fillets were cast in the ribs for fixing the ceilings.

Water and drain pipes and flues for the incinerators are in vertical ducts, two to a block. The sides of the projecting portions of the ducts are of reinforced concrete and act as columns.

Fig. 1.

On the ground floor the finish is $\frac{1}{2}$ in. mastic asphalt on 1 in. of sand-cement mortar in the dwelling rooms, and $1\frac{1}{2}$ in. granolithic in kitchens and passageways. In the upper stories a timber floor is used in the dwellings and schoolrooms, and $2\frac{1}{2}$ in. of granolithic in the kitchens, etc. The playground on the roof is finished with insulating slabs, and other roofs are finished with 2 in. to 4 in. of clinker concrete covered with bituminous sheeting.

Round mild steel reinforcement is used in the columns and square twisted high-tensile steel elsewhere. The concrete mixture was (by volume) about 1 part of ordinary Portland cement, 2 parts washed sand, and 3 parts crushed whinstone. A weight-batching machine was used, loaded by a $\frac{3}{4}$-cu. yd. shovel and feeding two 10/7 mixers. The proportions were corrected to allow for moisture in the aggregates and for particles larger than $\frac{3}{16}$ in. in the sand. The concrete was discharged from the mixers into petrol-engine driven wheel-barrows.

The City Architect is Mr. A. G. Forgie, A.R.I.B.A., and the Housing Executive Officer Mr. M. Murchison, F.R.I.A.S. The associated architects are Messrs. Williamson & Hubbard, F./A.R.I.B.A., and Messrs Kinnear & Gordon were the structural engineers. The contractors for the reinforced concrete and building work were Messrs. Hepburn Bros. The reinforcement was supplied by the Square Grip Reinforcement Co. (Scotland), Ltd., and the precast facing slabs by the Scottish Orlit Co., Ltd.

Residential Flats in London.

THE estate being developed at Clapham Park by the Wandsworth Borough Council will provide 182 flats of various sizes, a nursery school, and laundries. The scheme comprises three six-story, five five-story, and one four-story structures; tank rooms and motor rooms add a further two stories at some points, and boiler houses and fuel stores are provided in basements in two of the buildings. *Fig.* 1 shows three of the buildings under construction. The structures are reinforced concrete frames with 11-in. cavity brick walls, which also cover most of the external columns. The parts of the structures below ground level are entirely in reinforced concrete with retaining walls and raft foundations; elsewhere independent bases and footings are used, resting on clay. The concrete was a 1 : $1\frac{1}{2}$: 3 mixture. The architects are Messrs. Harold Baily, Sutcliffe & Associates, and the consulting engineers are Messrs. John Liversedge & Associates. Messrs. Trollope & Colls, Ltd., are the contractors.

Fig. 1.—Three Buildings during Construction.

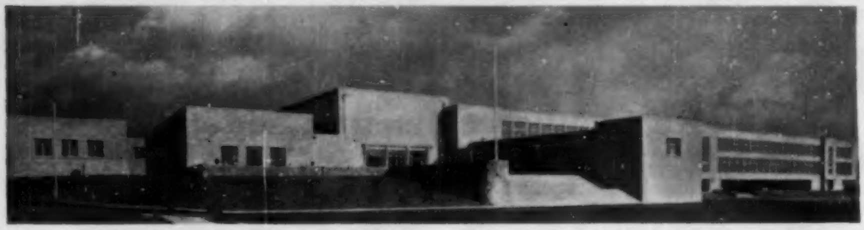
School at Hanley, Staffs.

THE new Hanley High School has accommodation for 600 pupils. The classrooms and laboratories are in two parallel wings about 360 ft. long and 140 ft. apart, with lavatories and cloakrooms joining the two wings. The classrooms and cloakrooms are on the ground and first floors and, by taking advantage of the slope of the site, covered space for cycles, stores, changing rooms, etc., is obtained under the buildings on the lower side of the site. These buildings are of steel-frames encased in concrete. The lintels over windows and the staircases are of reinforced concrete. The other buildings are entirely of reinforced concrete framed construction with brick elevations. The basement heating chamber, 14 ft. deep, is designed to resist a substantial head of water. Over the heating chamber is a tower 50 ft. high, and in this are water-storage tanks and a staircase to the first floor.

The gymnasium, dressing rooms, kitchen and dining room are single story buildings with reinforced concrete frames at 10 ft. centres; this spacing is also used in the assembly hall, stage, store, and concourse. Over the concourse is an exhibition hall which gives access to the balcony at the rear of the assembly hall, and over the store is a music room.

By taking advantage of the site levels the floor of the administration building is suspended to form a garage under, and the back wall of the garage retains the forecourt which gives access to the concourse and assembly hall.

With the exception of the floors and roofs of the classroom and lavatory buildings, where precast members were used, all the floors and roofs are in-situ concrete with warming panels cast in the soffits of the slabs. The risers and returns to the panels were where possible cast into the columns during construction. As a precaution against settlement due to mining the buildings are separated by joints, which were also used to divide the long lengths of the classroom blocks. The foundations were also designed to give a measure of safeguard against the effects of subsidence.



The work was carried out under the direction of Mr. J. R. Piggott, F.R.I.B.A., City Architect of Stoke-on-Trent, by Messrs. G. Percy Trentham, Ltd. The reinforced concrete work was designed by the British Reinforced Concrete Engineering Co., Ltd., who also supplied the reinforcement.

Change of Address.

THE address of Messrs. John Liversedge & Associates is now 42 Portland Place, London, W.1 (telephone Langham 7881).

New Year Honour.

IN the New Year Honours, Mr. George Foster Earle, C.B.E., Chairman of the Associated Portland Cement Manufacturers, Ltd., is designated a Knight Bachelor.

MISCELLANEOUS ADVERTISEMENTS.

Situations Wanted, 3d. a word : minimum, 7s. 6d. Situations Vacant, 4d. a word : minimum, 10s. Other miscellaneous advertisements, 4d. a word : 10s. minimum. Box number 1s. extra. The engagement of persons answering these advertisements is subject to the Notification of Vacancies Order, 1952.

Advertisements must reach this office by the 23rd of the month preceding publication.

SITUATIONS VACANT

SITUATION VACANT. Consulting structural engineer, Westminster, requires experienced reinforced concrete draughtsman-detailer. High salary and good prospects for suitable applicant. Write, stating age, qualifications, and full details of experience. Box 3690, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Consulting structural engineer, Westminster, requires senior designer-draughtsman with first-class experience in reinforced concrete for responsible position. Experience in structural steelwork an advantage. High salary and good prospects for suitable applicant. Write in confidence, stating age, qualifications, and full details of experience. Box 3694, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Reinforced concrete engineers require experienced senior designer and two designer-detailers in their London office. Five-days' week and pension scheme. Write, giving full particulars of age, education, and previous experience, to Box C.E.918, 191 Gresham House, London, E.C.2.

SITUATION VACANT. Senior estimator required by well-known Westminster firm of civil engineering contractors. Apply in confidence, giving full details of experience, age, and salary required. Box 3702, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Supervisor required to take charge of all types of reinforcement fixing contracts. Applicants must have had previous experience in the control of labour and general contract work, be willing to travel, and be able to drive a car. The successful applicant will also be expected to undergo a training on a new technique for fixing reinforcement similar to structural steel erection. Drive and initiative are essential qualifications, and good prospects are offered for the right man. Superannuation scheme. Reply, stating age, experience, and salary required, to the PERSONNEL DEPT., T. C. JONES & Co., LTD., 91–95 Wood Lane, Shepherd's Bush, London, W.12.

SITUATION VACANT. Sales manager required by well-known company in Yorkshire, manufacturing concrete products. Preferably under 35 years of age, with comprehensive knowledge of sales organisation, administration, and modern methods. Ability to control and direct representatives and initiate sales-promotion schemes. Preference will be given to applicants with knowledge of concrete products, including cast stone and patented concrete floor beams, or with sales experience in the allied trades. First-class opportunity offered to join organisation with policy of expansion. Replies, with details of age, experience, and salaries received, to Box 3703, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Soil mechanics engineer required to take charge of laboratory in Midlands. Applicants should be qualified men with at least four years' experience preferably in a commercial laboratory. A knowledge of geophysical surveying would be an advantage. Apply, stating age, experience, and salary required, to Box 441, 19/21 Corporation Street, Birmingham.

(Continued on page cii)

MISCELLANEOUS ADVERTISEMENTS.

(*Continued from page ci*)

SITUATION VACANT. Structural engineering designer required. Must be experienced and capable of designing reinforced and prestressed concrete. Experience of foundation work an advantage. Salary range £600 to £900. Apply in writing, with full details of qualifications and experience. Box 3704, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Structural draughtsman required. Should have experience of reinforced concrete. Knowledge of prestressed concrete and foundation work an advantage. Salary range £400 to £700. Apply in writing, with full details of qualifications and experience. Box 4705, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. THE BRITISH REINFORCED CONCRETE ENGINEERING CO., LTD., Stafford, have vacancies for reinforced concrete designers and detailers, with experience, in their Stafford, Bristol, Newcastle-on-Tyne, and Glasgow offices. Staff pension scheme and five-days' week.

SITUATIONS VACANT. Reinforced concrete design staff, engineering assistants, and draughtsmen-detailers, age between 20 and 30, required by civil engineering contractors specialising in foundations, now enlarging recently-opened drawing office. Excellent prospects, salary and bonus, and pension scheme. Applications in writing, stating age, experience, and salary required, to WEST'S PILING & CONSTRUCTION CO., LTD., Columbia House, Aldwych, London, W.C.2.

SITUATION VACANT. Reinforced concrete firm of engineering contractors desire to employ a specialist or consultant on prestressed concrete flooring and structures. Write Box 4707, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Personal assistant to Managing Director required for reinforced concrete company. Applicants should be in early 30's, hold degree and A.M.I.C.E., and have plenty of site experience. Good salary and promising future. Write, giving age, qualifications, experience, and salary required, to Box 3706, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Reinforced concrete detailer-draughtsman required for progressive position with consulting engineer in Victoria Street, London, S.W.1. State training, experience, and salary required. Five-days' week and pension scheme. Box 3712, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Civil engineer (assistant) age 25 to 35. Applicants must have several years' experience of design and construction of heavy plant foundations and structures, including reinforced concrete. Degree or equivalent an advantage. Pension fund and profit-sharing bonus. Good salary. Apply, with full details of age, training, and experience to the CHIEF ENGINEER, ASSOCIATED PORTLAND CEMENT MANUFACTURERS, LTD., Portland House, Tothill Street, London, S.W.1.

SITUATION VACANT. Experienced designer-draughtsman, age 26 to 34, holding civil engineering degree or professional qualification, required by contractors in South Lancashire area. The ability to design and detail a large variety of works, particularly in reinforced concrete, to work independently, rapidly and accurately, is essential. A practical knowledge of site work an advantage. Applicants please state age, qualifications, and salary required. Box 3713, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Assistant required in London professional office. Must be experienced in reinforced concrete design. Knowledge of steelwork and soil mechanics an advantage. Qualified engineer preferred. Varied projects and interesting work. Age limit 25/30. Five-days' week. Apply with full particulars, and state salary required. Box 3699, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Energetic man required to take charge of the Reinforcement Department in the Cardiff office of T. C. Jones & Co., Ltd., whose local works are in the Rhondda. The successful candidate must have a good knowledge of design and detailing and should have experience of liaison between office, works, and site on all types of reinforced concrete work. Good prospects await ambitious man willing to work hard and assist in building a rapidly-expanding department. Five-days' week, Superannuation scheme, etc. Reply to PERSONNEL DEPARTMENT, T. C. JONES & CO., LTD., 95 Wood Lane, London, W.12, stating age, experience, and salary required. Interview in London or Cardiff.

SITUATIONS VACANT. Draughtsmen—senior and junior—with experience of reinforced concrete detailing. Design experience an advantage but not essential. Required by firm of consulting engineers in the west London area. Good pay and opportunities for advancement, affording long-term possibilities for adaptable men. Box 3708, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION WANTED

SITUATION WANTED. Structural and mechanical engineer with considerable experience of prestressed and general concrete, including manufacture and of factory design, equipment, and production, seeks post or partnership. Box 3709, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

FOR SALE

FOR SALE. Steel panels for flooring. 3 ft. by 2 ft., and other sizes. Keen price and delivery. E. STEPHENS & SON, LTD., Bath Street, London, E.C.1.

PATENT

The proprietors of British Patent No. 643,685, for "Improvements in Reinforced Brick Beams", desire to enter into negotiations with a firm or firms for the sale of the patent, or for the grant of licences thereunder. Further particulars may be obtained from MARKS & CLERK, 57 & 58 Lincoln's Inn Fields, London, W.C.2.

FOR HIRE

FOR HIRE. Lattice steel erection masts (light and heavy), 30 ft. to 150 ft. high, for immediate hire. BELLMAN'S, Terminal House, London, S.W.1. Telephone: Sloane 5259.

Published by CONCRETE PUBLICATIONS LTD., 14 Dartmouth Street, London, S.W.1. Telephone: Whitehall 4581
Printed by BUTLER & TANNER LTD., The Selwood Printing Works, Frome and London